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FOR THE
PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

The Perpetuation of Error in Text Books.—The lead of the steam valve.

QUESTION 204.—"*Why is it desirable to open the steam-port and admit steam at the end of the cylinder towards which the piston is moving, before the latter has completed its stroke?*

"Because it is essential, in order to insure a good action of the steam, that the maximum cylinder pressure should be attained at the very commencement of the stroke. If the steam-port was not opened until after the piston had commenced its stroke, some appreciable time would be consumed in filling the clearance space and the *steam-way* with steam.* It is also found, especially if an engine is working at a high speed, that a slide-valve worked by the ordinary link-motion will not open the steam-port rapidly enough to enable steam of the maximum boiler pressure to fill the space after the receding piston, unless the valve begins to open the port *before* the piston reaches the end of its stroke.

"Another advantage resulting from the pre-admission of steam consists in the smooth working of the engine at high speeds, a circumstance which reduces greatly the wear and tear of the working gear. As the piston approaches the end of its stroke, the pre-admitted steam forms a kind of elastic cushion, which is well calculated to absorb the momentum of the reciprocating parts at that instant. The pressure due to the momentum of these parts will of course, depend

* The *steam-ways* are the passages which lead from the steam chest to the cylinder, and are sometimes called steam-ports, but the term steam-ways is used to distinguish the passages from their openings in the valve-seat, which latter are more properly called steam-ports.

upon their weight and the speed of working, increasing directly as the square of the speed. It follows from this that the lead should increase with the speed, and that it should be greatest at high speeds. As has been shown before, this condition is fully accomplished by the ordinary shifting-link motion."

The extreme difficulty of eliminating erroneous statements from previous publications, or from translated originals, especially after many reiterations of error, is exemplified in the preceding quotation from a recent text-book.*

The original statement, made by good English authority about the years 1830 to 1835, has held its place in all text-books of succeeding date, has gone to misinform German students on its travels, and has come to America, translated, to impart error here. As a general assertion it may be correct that "it is essential in order to ensure good action of *the steam* that a maximum cylinder pressure shall be attained at the very commencement of the stroke," but as applied to a running engine it is altogether erroneous.

For *easy motion of an engine*, the prevention of shocks, and relief of bearings from excessive pressure, (and consequent friction and loss of power), it is desirable that as the piston approaches the end of its stroke, the exhaust shall have been closed so as to form a cushion that will absorb the momentum of the reciprocating parts and relieve the pressure on the slide-valve at its time of opening; and the back pressure will then be just that needed to give to the moving parts their proper velocity in the other direction. And then, *after the centre is well passed*, the pressure of steam should be slowly admitted, reaching a maximum not earlier (perhaps for high pressure non-condensing engines) than 1-15 or 1-12 of the motion of the crank; while the cut-off should be effected, both for good action of the steam and for the good action of the engine, instantaneously. It may be possible with small sizes of ports, and inadequate cross areas, or great length of passages that steam cannot follow a piston at high speeds, but such possibility exists only with improper proportions for high speed, and should not be remedied by lead.

The original statement of forty to forty-five years since, was not incorrect for the time; and if the conditions are all given, is not incorrect to-day.

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* Catechism of the Locomotive. M. N. Forney, M.E., New York, 1875.

About thirty-five years since, the slide-valve was made without lap; it just covered the ports at both ends. The skill of the workman was taxed to see how exactly the one steam-port should open and the other be closed. The motion then given to the valve was almost coincident to that of the crank, and the rate of opening was exceedingly slow, as both crank and eccentric had just passed their centres. The valve motion was then usually transmitted from the eccentric to the valve through light rocker arms and rods, and there was more or less lost motion in the transmission. Under such circumstances, there was a reason for lead of the eccentric, as well as valve, and both rule and reason had a warrant in facts.

When the lap valves were introduced, much difficulty followed, so firmly had the theory of *lead* been established, but the workmen have long since learned, if the books have not, how to get the thump out of a slide valve engine. After many years of practical experience, the writer does not hesitate to aver that nothing he ever learned cost him so much money and annoyance to *unlearn* as this rule and reason for the lead of a valve.

The effect of throttling the exhaust is no way a loss of power, but is simply a loss of capacity of the steam cylinder. For a given boiler a little larger cylinder is needed to perform the same work. There is, however, an absolute loss of steam and power on the back lead of the steam, and its recompense must be found in the ease of working and duration of the engine.

These remarks do not apply alone to slide-valve non-condensing engines. For engines of higher grade, in economy for use of steam, the cutting off of the exhaust is a great practical gain. With 24 to 26 inches of vacuum, if the exhaust is closed (cut off) at $\frac{1}{4}$ or $\frac{1}{3}$, a back pressure of vapor will pile up in the cylinder to over one-half an atmosphere, and thus relieve, or partially relieve, the engine of the momentum of the piston and parts, (it being premised that the piston *should be* as heavy as possible), and besides this, the condenser will have been relieved from any leakage of the piston itself, which leakage again, will have been saved for effective working of the engine. Leakage of piston packing, within the limit of troublesome back pressure thus becomes tolerable.

THE WATER COMMISSION.

The Commission of Engineers on the Water Supply of Philadelphia, have completed their labors, and their report is now before the City Councils and the public.

It is mainly local in its interest, and will undoubtedly meet with discussion from the city press that will prove instructive to the residents. Still the question was the water supply of a locality, and in this case the locality was one of the very large cities; so large as to occupy a place in the list of a hundred of the largest cities of the civilized world, and a report from six selected engineers, who should adequately treat the subject, should of necessity have possessed an interest beyond our city, land or country. It will, therefore, prove a disappointment to readers, both citizens and professional men, that in this report there is so evident an avoidance of the issues; and such a want of comprehensive view of requirement in future, and even of necessity to-day, and so complete an absence of novelty or individuality in conclusions or propositions.

In the origin of the Commission, it was admitted as unquestionable that there is now a deficiency of water supply in the present courses, pools, reservoirs or apparatus. It was also admitted, that water in the pools of supply is polluted by sewage of premises and manufactories. And further (incidentally perhaps), that the nuisance of sewage is becoming apparent in our rivers near the city, and extending already in evident effect forty or fifty miles below, into the broad bay. The discussion of these leading topics, the investigation of the circumstances now subsisting, the consideration of means for ameliorating the difficulties, the decision on the two points as to what ought to be done eventually, and what ought to be done now; formed subjects of ample importance for a Commission to act upon.

To take the briefest view of the question. The inadequacy of water supply has become painfully apparent to many citizens. The summer minimum supply is under fifty millions of gallons per day. (We think the supply of 1869 much under this). Supposing that this supply is inadequate (and here it is that the commission should have asserted itself positively), the call for new steam apparatus follows at once. The summer minimum quantity in the river is 240 millions of gallons per day. From this it would appear, that one-fifth of the whole water in the Schuylkill may be demanded to afford even the limited quantity named. With the unlimited demand on the

city service, which we now permit to be made by water users, and with the growth of the city in its present ratio, but few years (10 or 15) must elapse before a half of all the water the Schuylkill can furnish in the month of July will be needed for consumption alone. In such case, the quantity of water left in the river available for pumping, will not suffice to lift over 10 or 15 millions of gallons. It follows, that we *must* eventually (and quickly) have steam power equal to nine-tenths of our consumption. And this reasoning is little affected by the proposition to purchase the Flat Rock mill privileges, for they would only in the emergency allow the one-tenth to become three-tenths. The whole scheme of *water* pumping is what is called on the Mississippi river high water pilotage.

It may be demonstrated, that it will pay to use the water power we now own during the six or eight months that we have it, but it would need a careful array of figures to exhibit the fact, and this report does not contain either question in this form, or answer. But even with the six feet extra depth of water in the Fairmount pool (however desirable the head may be for turbines), the continuance of the turbine system of pumping is open to question. From a mechanic's point of view, one cannot discern the propriety of getting up a rotary motion through the complicated machinery of a turbine at high velocity, and gearing down to a reciprocating motion of a piston pump, when it is perfectly feasible (and good practical examples exist to demonstrate the facts) to pump directly by water pressure only. We do not believe that the turbines and pumps are averaging over 45 per cent. of duty, or ever have done so.

Passing from the supply and apparatus, which suggest another report rather than these few remarks, the purity of the water is even more important than the quantity. Here we have an admirable appendix by Col. Adams, who seems to have thought vigorously and soundly on the subject. A counteracting document is, however, found in the appendix of Booth and Garrett, who have cleverly ignored all the conclusions; but we think the sense of the community will side with the engineer rather than with the chemists. Authorities agree in saying that the presence of definite quantities of organic matter *do not* render water unhealthy.

The averment that it is not the quantity but the nature of the organic matter which determines the pollution, is happily illustrated by the remark that ten grains of sewage substance to a gallon might prove

deleterious, while one hundred grains of tea or coffee would be healthful and refreshing. This averment is permitted to lose all its force, by the subsequent assumption, when instituting comparisons of Schuylkill with other waters, that the organic matters present in each *are* the true measure of vitiation. Another assertion of the chemists needs qualification. They say, "River water has been used (as a beverage) from the earliest times without the slightest injurious effect." Take the Illinois river for an example (even before the Chicago sewage emptied into it). We think the residents on its "bottoms" would, as a steady drink, advise whisky!

Recurring to the nature of organic substances in water, we can say positively that water which has generated typhus fever of the worst character, has been found to have but very little organic matter, but the balance of all medical (not chemical) authority is, that in time sooner or later, water contaminated with sewage will become the vehicle of disease of fearful character if not extent.

With this fact before us, it is to be regretted that the recommendation for immediate construction of an intercepting drain to take off the sewage of Manayunk, the Chelten Hills and Germantown did not meet the unanamous approval of the Commission. Should this sewer be built at any future time, it will be found necessary to convey it across the river (under the dam, possibly), and extend it down to the Delaware; for it would never answer to discharge so much sewage as will come from the combination of these sources, together with the Mantua sewage, into the slow tidal stream of the Schuylkill below Fairmount dam.

It would have been very well if the Commission had discussed and expressed an opinion as to the condition of the Fairmount pool, and advised some steps for its purification.

The expectation that purity of water would be ensured in the winter by the removal of a few patches of ice, is too absurd to need argument to refute it. The probability is that a considerable part of the decomposition of Manayunk sewage at that season takes place inside the city water pipes themselves, as there only is the water warm enough to decompose organic matter. At all events denuding one thousandth part of the surface of the river in ice getting, is by no means the exposure which will constitute perfect "ærating" (if that is the right word).

But even if this proceeding effected *all* that could be wished in winter, the low water summer condition of the pool is truly deplorable, and embankment and excavation is immediately requisite. Not only should the flats which are alternately flooded and laid bare by the fluctuations of the stream be removed, and stone walls or gravel banks be established on the margin, but the vegetable matter of the bottom should be dredged to such depth, as will prevent active decomposition of any substances which may be deposited.

The condition of the Delaware point of supply, can only be alluded to say that it is even worse than that of the Schuylkill.

There are other matters disposed of in the report—the slack water system with reservoirs for supply, the Delaware river scheme, and the Perkiomen scheme. But to these the adverse opinion of the Commission will meet general approval.

We should have liked to discuss the nature of the territory which forms the watershed of our rivers, from which we must look for supply; its general aridity, absence of standing water, lakes or ponds, and infrequency of perennial springs (making a deficiency of natural storage), and especially the immediate effect of low dew point upon rainfall, etc., etc.; but the length of this notice compels abrupt termination, as it has compelled assertion rather than explanation or argument.

Announcement of Lectures to be given before the Franklin Institute at their Hall, commencing Thursday, November 4th, 1875:

Six Lectures by Prof. Edwin J. Houston, on Acoustics,
November 4th, 11th, 18th, 25th, December 2d, 9th.

Two Lectures by William H. Wahl, Ph.D., on Gas Lighting,
December 7th, 16th.

Four Lectures by Mr. D. D. Willard, on Mathematics,
November 9th, 16th, 23d, 30th.

Two Lectures by Theo. D. Rand, Esq., on Mineralogy,
December 14th, 21st.

The order of Lectures after the holidays will be given in good season:

One Lecture by C. B. Dudley, Ph.D., on Artificial Ice.
Three Lectures by Prof. P. E. Chase, on Natural Physics.
Three Lectures by Mr. Robert Briggs, on Steam Boilers.
Two Lectures by Prof. D. Cope, on Paleontology.
One Lecture by Mr. Jos. Zentmayer, on The Lens.
Two Lectures by Prof. R. E. Rogers, on Chemical Force.

Besides these, there will be a number of Lectures, the Subject not yet fully decided upon, but which will be announced in due time.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 20th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present two hundred and thirty-three members and thirty-seven visitors.

The minutes of the stated meeting for September were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their meeting held on the 13th inst., there were six persons elected members of the Institute and the following donations made to the library:

Explorations of the Colorado River of the West and its Tributaries. Explored in 1869, 1870, 1871 and 1872, under the direction of the Secretary of the Smithsonian Institution. Washington, 1875. From the Secretary of the Interior.

The Uranian and Neptunian Systems, investigated with the 26-inch Equatorial of the United States Naval Observatory, by Simon Newcomb, LL.D. Washington, 1875. From the Author.

Jahrbuch der K. K. Geologischen Reichanstalt. Vol. 25, January to March. Vienna, 1875.

Verhandlungen d. K. K. Geologische Reichsanstalt. Nos. 1 to 5 inclusive. 1875.

Die Culm Flora des Mahrisch—Schlesischen Dachschiefers von D. Sturr. Vienna, 1875. From the K. K. Geological Society.

Forty-second Annual Report of the Royal Cornwall Polytechnic Society, 1874. From the Society.

Third Annual Message of William S. Stokley, Mayor of the City of Philadelphia, with the Accompanying Documents, June 24, 1875. From the City Government.

Transactions of the Royal Irish Academy. Vol. 25, XI. Report on the Strength of Single-riveted Lap Joints, by Bindon B. Stony, M.A., with Tables and Plate XXV. Dublin, 1875. From the Society.

Quarterly Weather Report of the Meteorological Office. Part I, January to March, 1874. Report of the Meteorological Committee of the Royal Society for the year ending December 31, 1864. From the Meteorological Committee of the Royal Society, London.

Amphiorama ou la Vue du Monde. 2me Notice la Marée dans le Bassin du Spitzberg et le flat qui contourne la tête du Groen-

land; aussi l'arrivée de la lumiere au pôle pour la premiere fois observé et decrit, par F. W. C. Trafford. Zurich, 1875. From the Author.

Tables, Meteorological and Physical, prepared for the Smithsonian Institution by Arnold Guyot, P. D., etc. Washington, D. C. From the Smithsonian Institution.

Bulletin of the National Association of Wool Manufacturers, July to September, 1875. Boston, Mass. From the Association.

Annual Report of the Board of Regents of the Smithsonian Institution for the year 1874. Washington, D. C. From the Smithsonian Institution.

The Actuary also reported that in accordance with the recommendation of the Committee on Science and the Arts, the Board of Managers have awarded the Scott Legacy Premium and Medal to R. B. Goodyear for his improvements in box motions for looms.

The Secretary read from the minutes of the Board of Managers the report of the Committee on Publication in relation to reprinting the reports on "Steam Boiler Explosions" and "Strength of Materials," and the action of the Board adverse to the reprinting, and also to the expenditure of $1000 for making tests of iron and steel, and on motion, this action was approved.

The Committee on the letter of the British Minister to the United States, in relation to the Albert medal of the Society of Arts, presented the following report, which was adopted, with the appended resolution:

The committee to whom was referred the consideration of what should be done in relation to the request of Sir Edward Thornton, "that the Institute should present to the Society of Arts, London, the names and testimonials of persons eminent in the arts who could be recommended as worthy of the 'Albert medal,'" ask to report:

That the nomination of such gentlemen is in the opinion of your committee a subject of great delicacy, and that however honorable the endorsement and advocacy of the Institute might be, the public announcement of the fact, unless followed by the desired result, would be a source of annoyance to those whom it sought to advance.

Any person who should become the recipient of such an acknowledgment of ability and merit, would be more gratified by ignorance of the steps which promoted it, and would feel aggrieved to be informed of cavils or personalities that may have ensued.

When we examine the record of the lives and thoughts of our eminent men of former days, it is noticeable how detraction and calumny, bickerings and discontent have followed them in some proportion to their very superiority, and it is desirable that such may

not find public expression in prelude to the declaration of opinion from *our* Institute to the Society of Arts.

The Institute at a yearly election chooses a Board of Managers, to whom it confides its interests in various ways, and it seems to your committee that the choice of persons worthy of honor had best be referred to them, and that in this particular the expression of opinion by the Institute can be safely placed in their hands.

As a parallel case we instance the nomination for honorary membership, which is effected by the Board of Managers, who send the names to the Institute for subsequent election and ratification by vote. Similarly, the nomination of gentlemen who would honor the medal proffered by the Society of Arts, could with propriety be made to the elective body—in this case, the Society of Arts—and if the result is the donation of the prize, the instrumentality of the Institute would then become public.

With these views the committee submit the attached resolution, and ask to be discharged.

ROBERT BRIGGS,
B. C. TILGHMAN,
S. W. ROBERTS.

Hall of the Franklin Institute, Phila., Oct. 20, 1875.

RESOLUTION.

Resolved, That the Board of Managers are hereby requested to consider and act upon the communication of Sir Edward Thornton relating to the "Albert medal," and in behalf of the Institute recommend such persons as in their judgment are worthy to be associated publicly with those eminent men who have already received this evidence of estimation.

THE COMMITTEE on establishing a Museum of Industrial Art in Philadelphia, presented the following report, which was adopted:

The project of establishing a museum, having for its object the advancement of the industrial arts, is one in which the Franklin Institute, above all other educational institutions, should take an active part, as no better means could be devised for carrying out the objects for which it was organized, than by bringing together specimens of products of the various industrial arts from the earliest period down to the present time, and showing by comparison the wonderful progress made during the various periods of the world's history. This can only be done by founding such a museum, as it is now proposed to do, and it is fortunate for us that so many of the means necessary to make it successful, are all ready at our hands. The act of the State Legislature, authorizing the loan of a million of dollars, and creating the State Board of Supervisors, was to erect a memorial building to be used as a museum for all time, and this building has

been planned with a view to its adaptation for the purposes of an art museum, and competent persons have declared it to be most admirably adapted to the purpose.

A committee of citizens was organized for the purpose of applying to the proper authorities for the use of memorial building for this purpose, and through the kindness of its Chairman, Dr. Wm. Pepper, your committee were invited to be present at a meeting held on the 7th inst., at which the matter was fully discussed, and a plan of organization was adopted, and on the 12th inst., it was laid before the bodies having charge of the building, consisting of the State Board of Supervisors, the Park Commission, and the city officials, and was referred by them to a committee consisting of the Hon. Alex. Henry, of the State Board, Theo. Cuyler, Esq., of the Park Commission, and John L. Shoemaker, Esq., of the City Councils, and the Hon. M. McMichael, the Chairman of the meeting. These gentlemen have the matter in their charge, and will report to the committee of citizens at some future time, and which your committee most sincerely hope may be in favor of the plan of organization proposed, and asking to be continued, we remain

J. E. Mitchell, *Ch'n*,
John Sartain,
Coleman Sellers,
J. B. Knight.

Mr. Solomon W. Roberts announced the death of Mr. Wm. E. Morris, civil engineer, a life member of the Institute, and gave some account of his life and service, and moved the adoption of the following:

Whereas, William E. Morris, civil engineer, an old and highly respected member of the Franklin Institute, died suddenly of disease of the heart, on Friday, October 15th, 1875, in the 64th year of his age.

Resolved, That the Franklin Institute deeply regrets the death of Mr. Morris, by which it has lost a valued member, and the city of Philadelphia a highly respected and eminently useful citizen.

Resolved, That in his professional career as a civil engineer, for a long period of years, Mr. Morris has shown great industry, strict integrity, and marked ability, and has left a reputation for uprightness and trustworthiness which is well worthy of record and of imitation.

Resolved, That a copy of these resolutions be signed by the officers of this meeting, and transmitted to the family of Mr. Morris.

Mr. Coleman Sellers seconded the motion, and expressed the wish

that Mr. Roberts would prepare his remarks for publication: whereupon the preamble and resolutions were adopted.

The Secretary presented his report on novelties in science and the mechanic arts, embracing Brayton's Ready Motor, or High Pressure Gas Engine, and by the aid of the lantern, gave a description of it, and with the assistance of the inventor, illustrated its principle, and the mode of operating it.

Also, The National Timber Preserving Company's apparatus for impregnating timber with antiseptics, by forcing a solution through the pores of the wood.

The Secretary stated that the commission on the water supply of the city had completed its labors, and that he had been presented with a copy of their report, which he presumed would soon be ready for distribution.

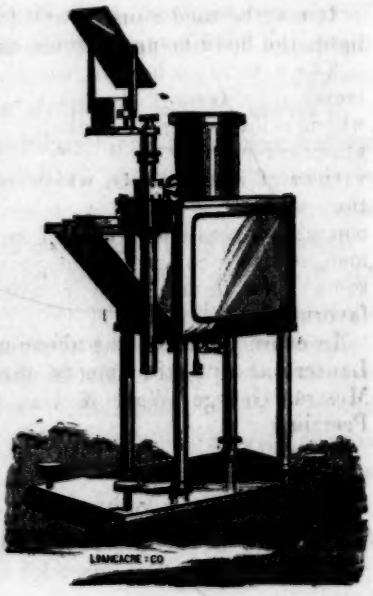
Mr. Edward Brown offered the following, which was adopted:

Resolved, That the Secretary be requested to send notice of the Centennial Exhibition to kindred foreign societies, and extending the privileges of our reading room to their accredited members, at the discretion of the President.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

A New Form of Magic Lantern.—As some of our readers are no doubt interested in the subject of magic lanterns, as they have of late years been developed into philosophical instruments for the demonstration of the principal phenomena of optics, we publish in this place a late report of the Committee of Science and the Arts, on one of these, which seems to have achieved the widest reputation, together with a wood-cut of the same, which has been furnished to us by the manufacturers, Messrs. Geo. Wale & Co., of Hoboken, N. J.



HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, May 30, 1875.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the College Lantern, and attachments, of George Wale & Co., report that they have examined the articles specified, and find them worthy of high commendation. The lantern itself is convenient in size, tasteful in design, and of ingenious construction. The frame is of heavy brass, the sides being of sheet metal, and screwed upon it. The general workmanship is good, and the finish sufficient for apparatus of this kind.

The point of special merit, however, is the very simple and satisfactory device adopted for converting the horizontal lantern into a vertical one. This is effected by hinging horizontally the plate which carries the anterior lens of the condenser. By throwing this up into a horizontal position, and placing the inclined mirror in the space thus formed, a most excellent vertical lantern field is obtained. The attachment of the arm which carries the objective to this movable plate, is also an ingenious and effective arrangement. The polarizing attachment appears also to be worthy of special mention. Its position and the facility with which it may be put in place, and operated, are points of real practical value. The microscopic and spectroscopic attachments are well arranged, and do their work in the most satisfactory way. In use the lantern performs admirably, giving a bright and uniformly illuminated field, with all the above mentioned attachments.

It may be used equally well for the oxyhydrogen or the electric light, the body being mounted on four upright pillars.

The committee believe, therefore, that the College Lantern, manufactured by George Wale & Co., is the best lantern of high grade which is for sale in the country. It is an excellent piece of apparatus, exceedingly well arranged, and convenient. It has a great variety of attachments, which can be readily and rapidly fitted to it, thus making it really a universal lantern. To this opinion, the committee would add that of several distinguished scientific gentlemen, entirely competent to judge of its merits, having had it for some time in use. Their testimony is universally and strongly favorable.

In consequence of the above-mentioned advantages of the College Lantern and its attachments, the committee recommend the award to Messrs. George Wale & Co., of the Scott Legacy Medal and Premium.

(Signed.) GEORGE F. BARKER, *Chairman.*
CHAS. H. MILLS,
CHAS. BULLOCK.

By order of the Committee on Science and the Arts.

J. B. KNIGHT, *Secretary.*

Goodyear's Improvement in Shuttle Box Mechanism.

HALL OF THE FRANKLIN INSTITUTE.

Philadelphia August, 27th, 1875.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination, the application of Robert Burns Goodyear, for Improved box motion.

Report: After visiting several factories where these improvements are in daily service on power looms and investigating the state of the arts, find this improvement in drop box looms, is the subject of Letters Patent of the United States, No. 144,089, dated October 28th, 1873 and denominated, "improvement in shuttle box operating mechanism," and its object is to effect the various adjustments of the drop-box of looms, for weaving the description of goods known by the name of checks, or ginghams; and of all the materials in common use for cloth, as cotton, woolen, linen, and silk, or a mixture of them. The check is formed by having the warps striped in a certain order, by warping yarn of different qualities either as to number or color, and crossing these stripes in weaving, at the proper intervals to form squares, with the corresponding kinds of weft; checks therefore are woven with a variety of shuttles, corresponding to the number of colors, or kinds of yarn used as weft, to form the pattern with the warp. The shuttles therefore must be changed, for the purpose of weaving with them, and this is done, by rendering the box which contains them movable, at least at one end of the lathe, and forming the box with a separate berth for each of the shuttles, the movement of the whole box is therefore made in a certain measured manner, corresponding to the breadth of each of the separate berths, so that any of the shuttles, may be brought as required, to the plane of the race and the reed, and used till another change becomes necessary, these changes are regulated by an index or pattern wheel.

There are three methods in common use in which the box is made for effecting the required change of the shuttles. By one method, it is made to slide vertically, with the berths or shuttle box shelving above each other, parallel with the race, this is called the drop-box and was invented by Robert Key in 1760. Another method is the swing box, which is made to vibrate horizontally in the plane of the race, by being attached to a pendulous framing, supported on pivots from the lathe, and Dr. Cartwright has the merit of this invention patented in 1792.

Another method, is the revolving box, patented by W. Boyd of Connecticut in 1828. It was not however until the year 1830 to 1835, that light fancy fabrics with small patterns began to be exten-

sively introduced in manufactories. Checks and ginghams are generally heavy made fabrics, about the set of calicoes; and therefore no special adaptation of the looms is necessary for them, excepting that dependent on the motion for changing the shuttles. The first method, or drop-box, from its stability of action, is the one adopted by Mr. Goodyear, and the mechanism for moving this kind of a shuttle box is the object of his patent. The number of plans that have been tried for moving shuttle boxes, is very numerous, and by far the largest number of them have not succeeded. The essential features in a complete power loom for making the various kinds of checks and ginghams are an index for the pattern, which must have an extensive range such as can only be attained by using an endless chain; the mechanism for shifting the shuttle box, must be so made, that any shuttle can be brought into play, so as to make any pattern that can be imagined. If the box is not brought to its proper position when shifted, there must be a protection, to stop the loom to prevent damage being done to the shuttle box, or the mechanism must be so contrived within itself as to become a protector. The shuttle box must be free from all injurious influences of a dangling, or uncertain action.

By the peculiar construction, as will be readily seen by reference to his patent. Mr. Goodyear has essentially filled these conditions, and in practice we find, the shuttle-box operating mechanism to move the boxes with ease and precision, so that the shuttles can be used in the sequence desired; without danger of damage to the mechanism, to the shuttle-boxes, or to the picker motion, and that the pattern is controlled by endless chain, giving any practical range desired.

Mr. Goodyear has devoted nearly 30 years of his life in perfecting looms for weaving, with movable shuttle-boxes, during which time he has made numerous inventions, among which the most notable was an invention in 1848 called the "pins of different lengths" and which placed the box loom far in advance of all previous ones, and almost on a par with the one shuttle loom of that day as to simplicity of action and speed. The pin in the index or pattern wheel prior to the Goodyear invention merely designated a movement of the box from one berth or shuttle to another, resulting in frequent mistakes by putting in the wrong color; thus spoiling the pattern and requiring ceaseless attention and great skill on the part of the weaver, and causing power loom weaving to linger for a long time behind the hand loom. In the Goodyear invention the Index pins were made of different lengths, each length designating a color, thus bringing check weaving by power to a definite principle, and enabling plain cloth weavers to tend these looms, besides increasing the speed of the looms from eighty shots a minute to one hundred and thirty, a speed which is not excelled by any other looms having movable shuttle boxes.

And Committee recommends that the Scott Legacy premium and medal be awarded to Robert Burns Goodyear, for his improvement in shuttle box mechanism, as Patented October 28th, 1873.

Signed, H. F. West.
Coleman Sellers, Oct. 6th 1875. L. L. Cheney.
Barton H. Jenks.

By order of the Committee on Science and Art.

J. B. Knight, *Secretary.*

Flanged Pulleys.—There are some places where the use of flanged sides to retain the belt upon the faces of pulleys, is desirable if not essential. Thus for driving a ball governor, which requires no power whatever when in motion at uniform speed, but demands an application of force sufficient to lift the balls from their position of rest into their place of rotation in the very short interval of time of starting an engine, (which starting is generally without work upon the engine), flange pulleys are almost essential to keep the belt from sliding off the edge of one or the other of the pair of pulleys. For tightners on some classes of machines and for mule pulleys the same necessity exists. In such cases most machinists have, however, encountered the difficulty especially with long belts, arising from the belt riding upon the flange or its side, and if not running off altogether, of stretching the edge in places and thus destroying the belt rapidly.

By giving the flange the correct shape indicated in the figure, it will be found possible to avoid any of these accidents, and that flanged pulleys will become as serviceable as any others. The shape to be given is simply that obtained by cutting away the base of flange (as at A A) and allowing the edge of the belt to come in contact with the outer periphery only. Pulleys thus formed, present to the unaccustomed eye of a machinist, a somewhat strange look, and except the reason were explained, he would think some bad workmanship had cut away the fillet at the base of the flange improperly. But the fact is positive, and the eye soon appreciates any such essential feature. It may be added that long belts, whether on flanged or plain faced pulleys, had best be crossed for regularity of velocity and quantity of power to be imparted by them, as well as for durability.

Civil and Mechanical Engineering.

THE LOWELL AND LYNN COMPOUND PUMPING ENGINES.

MR. JAMES H. HARLOW.

With note by the Editor of the JOURNAL.

From the Transactions of the American Society of Civil Engineers. Extracted from discussion on papers before the Society at their seventh annual meeting in June, 1875. In the course of proceedings when the subject of pumping engines was under consideration, Mr. James H. Harlow, M. A. S. C. E., made the following statement:

The Lynn and Lowell engines are considered the best pumping engines in the country, because they gave the highest duty of any on special trial, viz.: 103,923,215 and 93,002,272 feet pounds respectively. A high duty in a special test is of no practical value to those using the engine, except to show whether the engine is a good or poor one. An engine that will not give a high duty on special trial will not be likely to give so good a duty on a yearly run.

The duty of an engine for *practical* purposes should be calculated on the *total* amount of coal used, without deduction of any kind whatever. The coal must be paid for, whether combustible or ashes. On a special test, I do not know why combustible is not as well as anything to calculate duty on; for in comparing two engines the amount of combustible should be taken into account. The point where these engines are to be beaten, if at all, is in their cost. If the interest on the extra cost of one engine over another, exceeds the cost of the saving in fuel, it will be cheaper to use the inferior engine. (This does not cover the whole question but is the main item.) The cost of the engine is understood to mean the cost of everything dependent on the style of engine.

In order to show what the Lynn and Lowell engines do, as they are usually run, I have prepared the accompanying table of work

done in May, 1875. The notes from which the table is compiled were taken by myself from the books of record kept by the respective engineers and are expressed in columns *A*, *B*, *F*, *G*, *H* and *J*; sufficient explanations are at heads of these columns. Column *C* gives the quotient resulting from dividing the number of revolutions by the minutes run. The rated capacity of each engine is 5,000,000 gallons per 24 hours, although each will do a little more. In order to pump 5,000,000 gallons in 24 hours the Lynn engine must make 18 6 and the Lowell engine 11·18 revolutions per minute. The average speed of the Lynn engine exceeds the above by 0·48 per cent.; the Lowell engine never came up to the speed above, the average being but 76·2 per cent. of 11·18 revolutions per minute. The reason for the low speed is, that the engine draws from a filter gallery that does not furnish a full supply for the engine. Column *D*, is the quotient of column *J*, divided by 5,000,000, the rated capacity of each engine. Column *E* shows the state of the pump-well. The pump-well of the Lynn engine is supplied with water through pipes, connecting with the ponds under a head of 20 to 25 feet, thus enabling the engineer to keep practically the same depth of water by opening or closing a gate at the engine house. The pump-well at Lowell receives its supply through a pipe connecting with the filter gallery, which in turn receives its supply by the infiltration of water through the gravel; thus it is out of the power of the engineer to prevent the variation in the well, which sometimes amounts to 12 feet. Column *I* is the total coal minus the ashes, divided by the total coal. Column *J* is the number of revolutions multiplied by the actual capacity of the pumps as determined by experts, viz. 186·7 and 310·4 gallons; the loss of action of Lynn pumps was 3·9564 per cent., and of Lowell pumps, 3·6497 per cent. Column *K* is duty by formula given at head of column, in which G = gallons, as given in column *J*; H = dynamic head, as given in column *F*, and W = weight of coal in pounds, as given in column *G*. Column *L* is a duty calculated on the assumption that the Lowell engine runs the same *length of time* as the Lynn and making a corresponding increase in amount of water pumped and coal used while running. The duty would then be calculated on the coal given for the Lowell engine, minus 960 pounds used for other purposes and increased by the same ratio as the times, between the Lowell and Lynn engines, plus 960 pounds.

At Lynn are two boilers (a more particular description of which may be seen in the report of experts* upon the trial of the engine,) both of which are generally in use. There is also a small boiler used for heating the building, but which was not in use in May. The boiler feed-pump is situated in the boiler-room, it is not connected with the engine, and takes steam from the main boiler. The experts† find that this feed-pump uses as much steam in 8 hours as would have been used in 52 hours, if connected as at Lowell. The jackets of the steam cylinder are supplied with steam from the main boiler.

It is the custom at Lynn to start with cold engine, boilers and water, to run several days at about 62 per cent. of the engine capacity and then to allow the fires to burn out, lie still a few days and start again. Before starting everything is cleaned up. The amount of coal allowed by the engineer was, in May 3900 pounds, or 355 pounds each time the fires were banked. There are also allowed 12,000 pounds for starting. This would give an average of 545 pounds each time the steam was raised after banking, and 1200 pounds each time steam was raised from cold water. This method of running would seem to be the most economical unless the deleterious effect of expansion and contraction (by reason of heating and cooling of the cylinder, which would add to the cost of repairs) would balance the saving in coal used. The force main is 20 inches in diameter and 1904 feet long.

At Lowell are three boilers of similar construction‡ to those at Lynn; one boiler was in use except when burning cinders, when two were used. A small boiler is used (in which steam is constantly maintained) for the steam-jackets; when the engine or main boilers are not in use 360 pounds of coal per day are required. During the time the engine is running, steam is supplied to the jacket from the main boiler, being shut off from the small boiler. The feed-pump is attached to the engine, takes water from the hot well and forces it through a heater 24·5 feet long and 2·5 feet in diameter, placed in the flue leading from the boiler to the chimney to the boiler. The engineer claims by this means, he utilizes 50° of heat that would otherwise be lost. There is

*Lynn Water Works. Report on the Trial of Duty and Capacity of the Pumping Engine. December, 1873.

†Report, page 20.

‡ Mr. Harlow is mistaken as to the construction of these boilers. Those in use at Lowell are shown at the end of this article.

PERFORMANCE OF LYNN AND

For references see

DAY OF MONTH.	MINUTES RUN. A.		REVOLUTIONS B.		REVOLUTIONS PER MINUTE. C.		RATIO OF QUANTITY PUMPED TO CAPACITY OF ENGINE. D.		DEPTH OF WATER IN WELL BELOW GUAGE. Feet. F. (a)	DYNAMIC HEAD PUMPED AGAINST. Feet. F. (b)
	Lynn.	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lowell.	Lowell.
1	.....	360	.....	2 867	.....	7·96	.....	0·178	20-28	163·75
2	.....	300	.....	2 766	.....	9·22	.....	0·171	20-26·5	163·
3	915	375	17 000	3 045	18·58	8·12	0·635	0·189	20-28	163·75
4	890	360	16 611	2 969	18·66	8·24	0·62	0·184	20-28	163·75
5	910	375	16 783	2 905	18·44	7·75	0·626	0·18	20-28	163·75
6	980	360	18 172	2 797	18·84	7·77	0·678	0·174	20-28	163·75
7	.....	365	.....	2 834	.....	7·77	.....	0·176	20-28	163·75
8	.....	370	.....	2 871	.....	7·76	.....	0·178	20-28	163·75
9	.....	360	.....	1 928	.....	5·36	.....	0·119	20 28	163·75
10	.....	370	.....	3 084	.....	8·33	.....	0·191	20-28	163·75
11	915	610	16 915	5 600	18·48	9·18	0·632	0·347	18-28	162·75
12	900	600	16 598	5 105	18·44	8·51	0·62	0·317	18-28	162·75
13	895	.....	16 630	.....	18·58	.....	0·621	.....	.....	.....
14	895	600	16 809	5 465	18·77	9·11	0·627	0·339	16-28	161·75
15	.....	435	.....	3 700	.....	8·5	.....	0·229	18-28	162·75
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	.....	575	.....	5 229	.....	9·09	.....	0·325	16-27	161·25
18	.....	455	.....	3 646	.....	8·01	.....	0·224	19·4-27	163·45
19	.....	445	.....	3 895	.....	8·75	.....	0·242	18·9-27·6	163·5
20	905	465	16 810	4 081	18·57	8·77	0·627	0·253	19-27	162·75
21	890	450	16 463	3 812	18·50	8·47	0·614	0·237	19-25	161·75
22	940	545	17 488	4 395	18·61	8·06	0·653	0·275	19-26	162·25
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	.....	615	.....	5 537	.....	9·	.....	0·344	16·6-28	162·05
25	.....	435	.....	3 765	.....	8·66	.....	0·233	20-28	163·75
26	900	485	16 588	4 024	18·43	8·3	0·619	0·25	19-28	163·25
27	890	520	16 530	4 622	18·27	8·89	0·617	0·287	18-28	162·75
28	900	485	16 754	4 343	18·62	8·95	0·625	0·27	18-28	162·75
29	.....	525	.....	4 834	.....	9·21	.....	0·3	18-28	162·75
30	550	.....	12 322	.....	22·44	.....	0·46	.....	16·6-25	.....
31	915	570	16 800	5 608	18·36	9·84	0·627	0·348	.....	160·55
Total....	14 190	12 410	265 264	105 727	.....	.....	.....	.....	.....	.....
Average.	887	460	.....	.....	18·69	8·52	0·618	0·243	.....	162·95

Lowell Engines, May, 1875.

foot note, page 310.

TOTAL COAL USED. Pounds. G.		ASHES OR NON-COMBUSTIBLE. Pounds. H.		PER CENT. OF COMBUSTIBLE. I.		GALLONS OF WATER PUMPED. J.		DUTY PER 100 LBS. COAL. $D = \frac{G \times H \times 8\,31 \times 100}{W}$ K.		DUTY AT LOWELL, UNDER ASS'MPN AS STATED. L. (*d*)
Lynn.	Lowell.	Lynn	Lowell.	Lynn	Lowell.	Lynn.	Lowell.	Lynn.	Lowell.	Lowell.
.....	2 158	.....	533	.....	.....	.....	889 917	.....	56 317 974	.....
.....	2 060	.....	.....	.....	88·1	.....	858 566	.....	56 658 130	.....
5 350	2 093	590	493	89·		3 173 900	945 168	80 771 604	61 672 014	84 551 279
4 850	1 960	600	212	87·6	89·2	3 101 274	921 577	87 062 640	64 213 194	90 632 042
4 850	2 060	570	.....	88·3	89·8	3 133 386	901 712	87 961 245	59 778 792	82 367 547
4 100	2 060	730	423	82·2		3 392 712	868 189	112 663 260	57 556 580	81 604 423
19 150*c*	1 786	.....	202	.....	88·7	12 801 272*c*	879 673	91 013 042*c*	67 264 470	....
.....	1 798	.....	210	.....	88·3	.....	891 158	.....	67 688 265	.....
.....	1 823	.....	186	.....	89·8	.....	598 451	.....	44 832 052	.....
.....	1 850	.....	222	.....	88·1	.....	957 273	.....	70 286 016	.....
5 750	2 620	540	416	90·6	84·1	3 158 030	1 738 240	74 776 948	90 052 440	102 581 490
4 800	2 491	540	1 252	88·8	41·7	3 089 847	1 584 590	87 897 531	86 343 628	99 055 205
4 800	360	480	.....	90·	.....	3 104 821	.....	88 067 265	.....	.....
4 300	2 600	720	1 137	83·3	56·3	3 138 560	1 696 336	99 313 545	88 013 640	100 165 704
19 650*c*	1 993	.....	595	.....	70·	12 498 258*c*	1 148 480	86 597 680*c*	77 217 364	.....
.....	360	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	2 703	.....	480	.....	82·3	.....	1 623 081	.....	80 753 208	.....
.....	2 509	.....	303	.....	87·2	.....	1 131 718	.....	61 487 817	.....
.....	2 360	.....	207	.....	91·3	.....	1 209 008	.....	69 855 597	.....
5 250	2 360	527	.....	89·9	86·2	3 138 427	1 206 742	81 390 222	72 855 542	90 729 480
4 850	2 162	510	623	89·5		3 073 642	1 183 245	86 284 120	73 829 400	94 584 130
4 300	2 460	900	293	79·1	88·1	3 265 010	1 364 208	103 379 720	75 040 707	89 602 600
14 400*c*	360	.....	.....	.....	.....	9 477 079*c*	.....	89 604 123*c*	.....	.....
.....	2 560	.....	695	.....	72·9	.....	1 718 685	.....	90 734 000	.....
.....	2 260	.....	.....	.....	88·6	.....	1 168 656	.....	70 619 656	.....
5 650	2 360	490	528	91·4		3 096 980	1 249 049	74 629 328	72 058 767	88 751 146
4 800	2 560	570	837	88·2	67·3	3 086 151	1 434 609	87 537 700	76 067 500	90 095 480
4 800	2 560	480	417	90·	83·6	3 127 972	1 348 067	88 723 930	71 475 883	86 502 714
15 250*c*	2 560	.....	225	.....	91·2	9 311 103*c*	1 500 473	83 128 642*c*	79 556 273	.....
4 100	360	580	.....	85·9	.....	2 300 517	.....	76 394 280	.....	.....
4 800	2 662	620	.....	87·1	.....	3 136 560	1 740 723	88 967 550	87 558 280	99 293 182
77 350	62 878	9 447	10 489	.....	.....	49 524 787	32 817 661	.....	.....	.....
4 834	2 329	590	403	87·8	83·3	3 095 299	1 215 469	87 179 069	70 924 279	89 752 920

no banking of fires under the main boiler, the fire being started new each morning from water at about 212° (as the engineer informs me.) The engine is run until it will run no more, reducing the steam to about 17 pounds pressure. The fires are allowed to remain until morning, when they are dumped and new started. The engineer allows 600 pounds of coal for raising steam, being, with 360 given above, 960 pounds used for other purposes than making steam when running. This engine is compelled to run each day, as its supply is drawn from the filter gallery, which will not furnish enough to run at maximum speed for a few days and then allow fires to burn out and rest awhile. The force-main is 24 inches in diameter and 2,666 feet long. If at Lowell there was used as good coal as at Lynn, the engine would give 4·5 per cent. better duty.* The following is deduced from the Table :—

			Column K.		Column L.
	Lynn.	Lowell	Lynn.	Lowell.	Lowell.
Duty on average combustible	4 244	1 926	99 299 350	85 764 608	107 739 900
" " coal used while running	.....	.....	107 230 881	102 950 604	.....
" " combustible used while running	.....	.....	122 130 844	123 362 070	.....

At the conclusion of Mr. Harlow's remarks, Mr. E. D. Leavitt said (referring to the report of the Committee on Pumping Engines, which was under discussion when Mr. Harlow presented his statement):

The superiority of beam-engines in respect to low cost for repairs is very clearly shown by the returns from Chicago, Louisville and Cleveland—this item, in many cases, ranks second to fuel only—and it is worthy of remark that at Chicago, with a duty of only 44,750,000 feet pounds; and coal at $8.56 per ton, water was delivered for 9·671 cents—while at Salem, with a duty of 59,000,000 feet pounds, and coal at $7.14 per ton, it cost 12·156 cents—per million gallons raised one foot high.

*References made in the table :

(*a.*)—Depth of water in well below guage—Lynn 20 feet, with but little variation.

(*b.*)—Water guage, each day run,—Lynn 62, and Lowell 60·5 pounds. Dynamic head pumped against—Lynn 163·25 feet.

(*c.*)—Total or average for this run.

(*d.*)—At Lynn two boilers were used when running, and at Lowell from May 11th to 18th and from May 25th to 31st; the remainder of the time at Lowell but one was used.

Comments by the Editor of the FRANKLIN INSTITUTE JOURNAL:

This very full and at the same time succinct statement and comparison of these rival engines is a highly acceptable addition to our American Engineering reports, and forms a supplement to the previous reports to the society, which have been published in its proceedings from time to time.

A preliminary remark which was made at the same meeting by Mr. David M. Green, M. A. S. C. E., coincides so entirely with the opinion of the writer that he thinks it well to corroborate it by an example. Mr. Green said: "*The necessary elements relating to any pumping engine and its appurtenances being given, it is quite practicable to determine in advance what will be the character of the performance of that engine.*"

The Lowell engine with boilers and appurtenances was built to specifications prepared by the writer of these comments, who controlled by stipulations as to performance and capacity, and constrained by some details of construction given in the advertisement for proposals, determined the proportionate dimensions, as also the specific mechanical construction of the several parts. The whole was built and completed under his direction, the work having been performed at the Southwark Foundry in this city, of which establishment he was superintendent.

The engine is a compound one of the rotative (Simpson) type, and was intended to follow established practice as to dimension, and in every particular detail, with the least of novelty or deviation, only allowing some adaptation of arrangements which had the warrant of years of use in England.

In weight of parts, and of the whole, and in general construction, it is thought to approach more nearly to a "Simpson" engine than any other in America.

There were some demands in the advertisement for proposals which were likely to be injurious to engine or boilers, and which were finally insisted upon by the Water Commissioners, such as a very dubious patent piston packing, no doubt very satisfactory to the patentee, but not so certain to a builder under penalty, or to a user for years of continuous service—a patent grate without dubiety, as the writer is confident that it occasions 3 to 7 per cent. of loss—a requirement for clustered metal water valves, of area referred to the area of the pump regardless of its capacity and stroke. This arrangement is wasteful

in wear, and invariably noisy, and the excess of dimension for the short stroke pump aggravated the difficulty, the whole being greatly inferior to the single three or four beat valve, of proper size for the work.

The engine was planned not for 5,000,000 gals. (24 hours) capacity as a maximum, but as a mean. It was intended to run from 8 to 14 revolutions per minute, and to pump the 5,000,000 gals. with 11½ revolutions, allowing 5 per cent. to be wasted in the pump and its valves.

The weight of fly-wheel had been specified, but was decidedly too low for ease of motion at the centres, and almost for passing them, if the speed was less than 10 revolutions per minute, *when the steam should be cut off at such a point as would give one hundred millions duty.*

The principal modifications of engine in the way of novelty, were a peculiar arrangement of joints in the parallel motion, whereby the radius bars and parallel bars were all single rods, a special cross-over casting for transferring the steam from small to large cylinders, and the attempt to regulate the engine automatically against variation of steam pressure in the boilers, by the German cut-off lifting cam actuated by a governor. The entire engine, with its independent bed-plate, horned beam, short stroke main pump, side pipe disposition, and general architectural effect was peculiar, but from an engineer's (not patentee's) stand point, not novel.

The boilers were of a style designed by the late Jos. Nason and the writer, for use at the Capitol in Washington, in 1856, and had had the sanction of 14 years' service, with average of nearly 12 pounds of water evaporated per lb. of anthracite coal consumed.*

---

* A report of two boilers at the U. S. Capitol, south wing, week ending Dec. 31st, 1859, showed six days, 92 hours' firing (the remainder of the time banked), all coal, used 53,165 lbs. ashes and clinkers weighed out 7300 lbs. Water evaporated by (tested) Worthington meter, 8448 cubic ft. (est. at 62½ lbs.) = 528,000 lbs. 62 square feet of grate were in use. The feed-water was heated by return steam from coils to 160°. There was burned, per square foot of grate por hour 9·3 lbs. coal or 8 lbs. of combustible (this quantity was probably overstated 10 per cent. as the banking coal was estimated as consumed in the hours of active firing).

The evaporation was 9·93 of water from 160° to steam (of 30 lbs. or) 259° to 1 of coal.

11·29 " " " 160° " " " " " 259° to 1 of comb'stible

Equivalent to 10·60 of water " 212° " " @ 212° to 1 of coal.

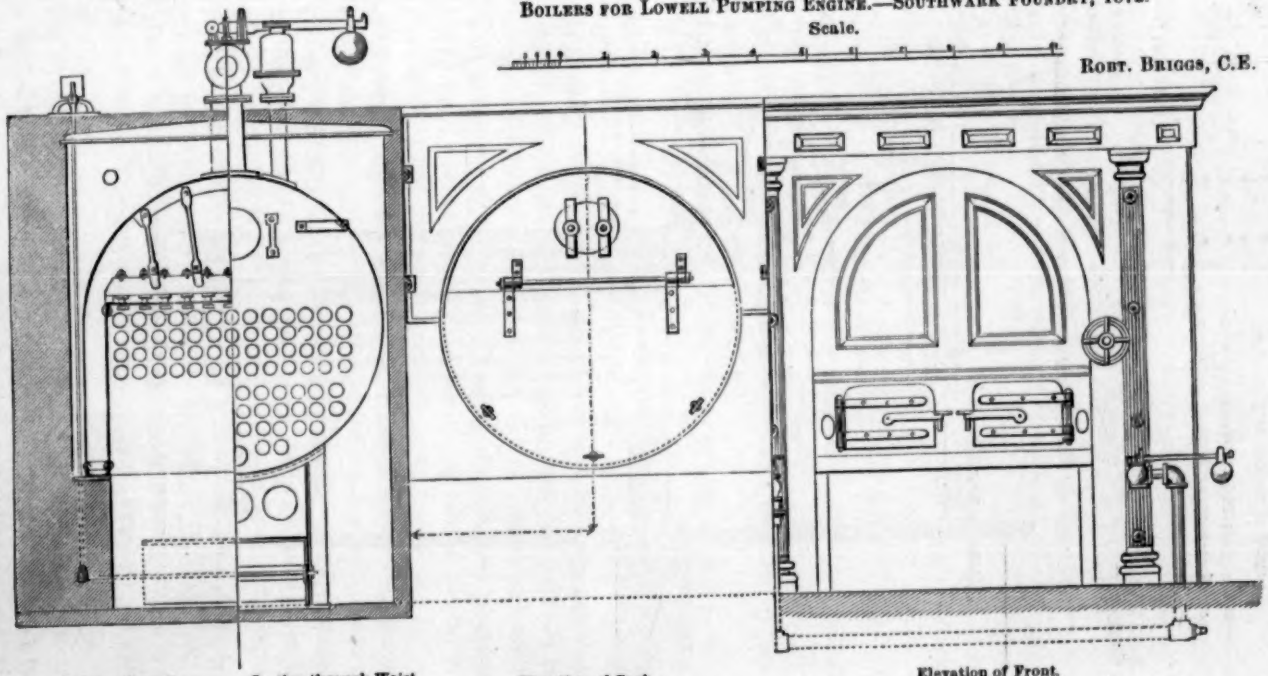
12·04 " " " 212° " " " 212° " 1 of combustible.

The weekly reports throughout the season 1859–60, averaged to correspond with this one.

BOILERS FOR LOWELL PUMPING ENGINE.—SOUTHWARK FOUNDRY, 1872.

Scale.

ROBT. BRIGGS, C.E.

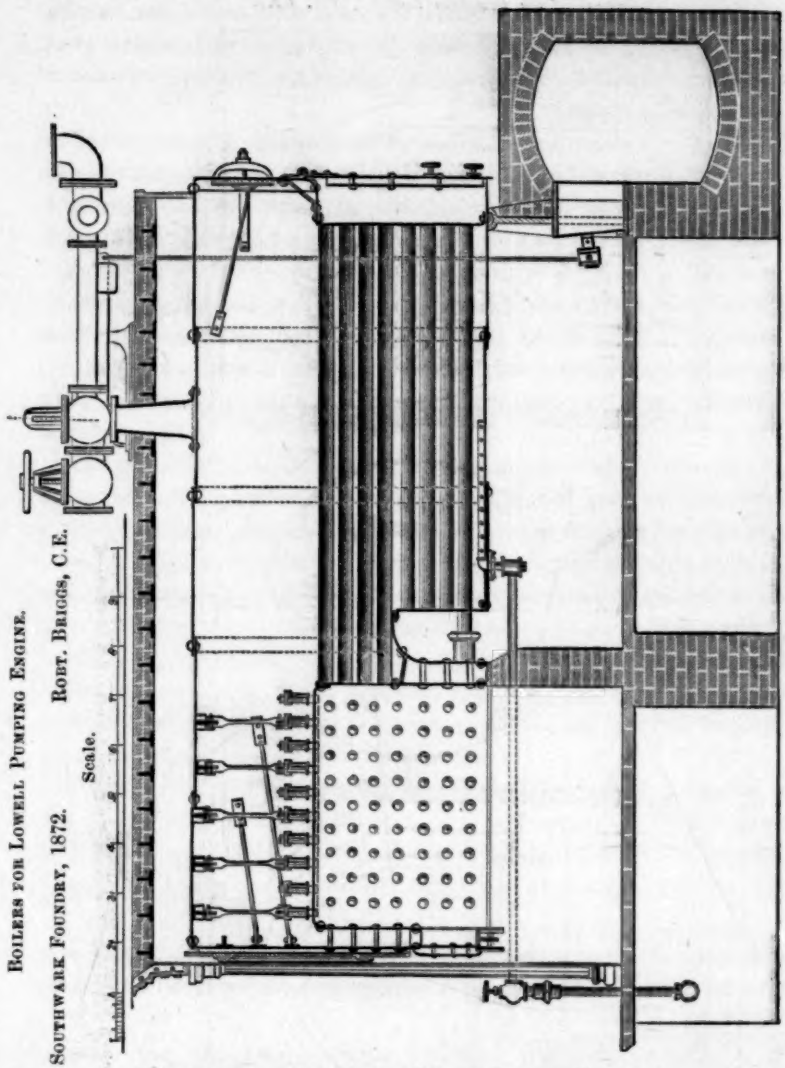


Section through Fire-Box.

Section through Waist of Boiler.

Elevation of Back.

Elevation of Front.



PROPORTIONS OF BOILERS FOR LOWELL PUMPING ENGINE:

Fire box surface, ...	86·0 sq. ft.	
Down take surface, ...	14·1 "	
Gap surface, ...	18·1 "	
Shell surface, (not est.)		
	118·2 sq. ft.	
52 upper tubes, 3¼ in. dia.		
51 lower " 3½ in. dia.		
surface,	759·3 "	
	877·5 sq. ft.	

Grate surface, 5 ft. × 5 ft. = 25·00 sq. ft.

Area of tubes (or flue section) = 3·47 "

Ratio of heating surface to grate = 35·1 to 1.

Ratio of flue section to grate = 0·139 to 1 :: 1 : 7 (nearly).

With this somewhat long premise, the remark of Mr. Green can be recurred to: it is quite practicable, to determine in advance what will be the *performance of an engine.* The Lowell engine was based on the following figures:

English experience has obtained 100 millions of duty (English millions, which exceed ours in the ratio of 112 to 100), with 60 to 80 lbs. of steam pressure, when the capacities of the high and low pressure cylinders bear the ratio of one to four, and by cutting off in the high pressure cylinder at one-third to one-fourth the stroke.

The exactness of these figures as data need not be questioned. It is evidently sufficient to admit or assume they have been reached under conditions of good construction, in most, if not all regards.

The requirement at Lowell is to pump 5,000,000 gals. (U. S. gallons of $8\frac{1}{3}$ lbs. each), under a head of 157 feet from level of sluice way to that of reservoir, through a 24-inch main of about twenty-five hundred feet length. The resistance of this main, calculated by Weisbach's formulæ, is very nearly 3 feet additional head. Giving a total head of 160 feet. [$160\frac{1}{2}$ to $163\frac{1}{2}$, table F, the limited supply from the filter galleries keeps down the level in the sluice way.]

$\therefore \frac{5{,}000{,}000}{24\text{ (hours.)}} = 208{,}333 : \frac{208{,}333}{60\text{ (minutes.)}} = 3472$ gals. per minute $\times$ 8·34 lbs. = 28,956 lbs. $\frac{28{,}956}{62{\cdot}4\text{ (lbs. per cubic ft.)}} = 464$ cubic feet, add 5 per cent. (for leakage† of pump piston, and at valves) = 487·2 cubic feet per minute.

Suppose the pump to be three feet in diameter and six feet stroke, its cubic capacity will be 42·41 feet. $\therefore \frac{48{\cdot}72}{42{\cdot}41} = 11\frac{1}{2}$ strokes (double) per minute. $11\frac{1}{2}$ strokes $\times$ ($2 \times 6' =$) 12 feet of stroke gives 140 (nearly) feet per minute as the speed of pump piston, evidently not too high a rate.

28,956 lbs. per minute is the net quantity pumped $\div$ 23 single strokes = 1257 lbs. to be pumped; each single stroke $\times$ 160 feet = 205,910 ft. lbs. $\div$ 1,000,000 (American millions are here taken as sufficiently accurate for this purpose) gives 0·206 lbs. of coal burned

† This allowance of 5 per cent. is shown to be correct by the Berlin example and thers, of which there are numerous reports.

for each single stroke, when the duty is attained. This coal *must generate* the steam to supply the cylinders.

Suppose the boilers to be capable of evaporating from and at 212°, eleven lbs. of water to a pound of coal burned. [A high, but not excessive rate of evaporation for boilers, used with pumping engines. The assumption of 100 millions duty demands excellence on all points.] ∴ 0·206 lbs. coal × 966·1 units of heat per lb. × 11 = 2189 units of heat per stroke.

Two values of pressure of steam were assumed, 60 and 80 lbs. (above the atmosphere) per square inch, The feed-water in either case can be taken at 60°. The temperature of steam at 60 lbs. = 307°, and that at 80 lbs. = 324°. Rankine's formula $h = 1114° + 0{\cdot}305\ T_1 - T_2$ for total heat of evaporation from water at T_2 to steam at T_1, gives

For 60 lbs. = 1146 units ∴ $\frac{2189}{1146}$ = 1·91 lbs. steam × 5·8 cubic ft. (per Rankine's tables) = 11·078 cubic ft. steam.

For 80 lbs. = 1153 units ∴ $\frac{2189}{1153}$ = 1·90 lbs. steam × 4·55 cubic ft. (per Rankine's tables) = 8·645 cubic ft. steam.

The relative assumptions for points of cut-off, were

For 60 lbs. = one-third the stroke ∴ 3 × 11·078 = 33·234 cubic ft. capacity of cylinder.

For 80 lbs. = one-fourth the stroke ∴ 4 × 8·645 = 33·580 cubic ft. capacity of cylinder.

The high pressure steam cylinder for Lowell was assumed at three feet diameter = 7·068 feet area; it was also taken at five feet $1\frac{5}{8}$ inches stroke, whence its cubic capacity was 36·297 feet, about 8 per cent. in excess of the actual dimensions given by the estimate. This excess was purposely allowed to ensure the result. There was a question whether upon the 5 per cent. of leakage there was not as much work (*i. e.*, coal) expended (or at least a portion of the work) as upon the water actually lifted, and the passage loss of steam is 1 to 3 per cent.

The high pressure cylinder being taken at 36·3 cubic ft., the low pressure one under the basic assumption becomes 36·3 × 4 = 145·2 cubic ft., and if the stroke comes conveniently at 8 ft., the diameter becomes 4·8 feet. In the Lowell example, the low pressure cylinder was made 4 ft. 9 in. diameter by 8 ft. stroke.

The coal has been found to be 0·206 lbs. per single stroke × 23 = 4·738 lbs. per minute × 60 = 284·28 lbs. per hour. [The boilers ought to be run on anthracite coal, at not less than 8 lbs. of coal per square foot of grate per hour; if pushed faster, proportioned as the heating surface in the Lowell boiler is, the gases of combustion will be overheated. The loss from this source, however, is not over 10 per cent. when the boilers are pushed over 12 lbs. of coal per square foot of grate per hour. Below 8 lbs. combustion, the coal begins to distill carbonic oxide gas, which is so intermixed with air and cooled down, as not to burn over the fire.] This requirement gave 35 square ft. of grate as the proper quantity to provide. The demands of the proposals were three boilers, of twenty-five square feet of grate each, which were furnished.

Two plates of elevations and sections of the boilers used at Lowell are given at the end of this article.

The actual quantity of coal fired (not consumed), as per table, columns A and G, was 5 lbs. per minute, with a duty of 71 millions, running an average of 7 hours, 40 minutes out of 24, and dropping the steam to 17 lbs. each day before stopping. At this last pressure, it can be shown that the engine cannot be performing at the rate of over 40 millions.

It can be safely asserted, that the Lowell engine *will* average for any length of time, 100 millions duty when it is run 23 hours out of 24, when the speed exceeds 11 revolutions per minute, and when the steam is kept at not less than 60 lbs., and is not throttled, but cut off in the high pressure cylinder, and until these conditions are complied with, it cannot be expected to come up to the estimated performance.

The engine was guaranteed for 75 (American) millions test duty.

The figures above given, are not made to suit the Lowell example, but the Lowell engine was proportioned from them. They are now transcribed from the original memoranda of estimate, unaltered, and are confidently offered to sustain Mr. Green's assertion, that "the performance of any engine may be stated in advance."

This system of computation can be extended to any order of engine, and the writer has used it with much satisfaction for computing dimensions of the intermediate-steam-chamber compound engine, with and without equality of work from the two cylinders, as well in the Woolf combination, which Simpson has adopted (and which the Lowell follows).

It is possible, of course, to calculate the performance of an engine more accurately and with fewer assumptions, but the method here exhibited is recommended for its facility of application, and is practically sufficient. It is based on actual results, and is divested of embarrassing conditions of pressures, expansions, condensation, balance of resistances, and all other theoretical considerations.

The proportions of the parts of the engine, fly wheel, air pump, force pump, pipe passages, valves, etc., the strength, thickness and weight of the several pieces, all demand computation by the mechanic, and ought to be as accurately determined as those for the capability of cylinders and other data pertaining to performance and result, should be by the engineer. It is difficult to say where the line of demarkation of the provinces of two kindred professions is to be made, but the figures given in this commentary are the primary ones, and will be found useful to both.

Having inspected the Lowell engine, at the completion of its erection; the writer was compelled, by the urgency of other business, to allow the testing trial to be carried on without his presence, and from that time until now, other avocations have prevented any, or but little consideration of its performance; and he wishes here to express his personal obligation to Mr. Harlow, for the excellent compilation and reduction of the records to readable form, as he has laid them before the Society of Civil Engineers.

The Mt. St. Gothard Tunnel is advancing with greater rapidity than has been made on any railway tunnel heretofore constructed. During the month of July the progress was as follows:—Length driven from north side, 113·40 meters; length from south side, 127·20 meters; total length driven during July, 240·60 meters. The position of these works on the 31st July was as follows:—North side (Goeschenen,) 2,330·90 meters; south side (Airolo,) 2,103·70 meters; total length driven, 4,434·60 meters; length remaining to be driven, 10,485·40 meters. Total length of tunnel, 14,920·00 meters. At this rate of progress, the entire work will have been completed by September 1st, 1878. It can scarcely be supposed that so great an undertaking will be carried to completion without accident, but with the usual allowances for engineering contingencies, it may be now assumed with safety, that the work will have been accomplished by the year 1880.

UNDER LONDON DOCKS.*

The difficulties that the East London Railway Company have had to encounter, and which they have now happily surmounted all but completely, have been of a more than ordinarily embarrassing and imposing character, and of more than one class, embracing, if we mistake not, obstructions legal and diplomatic, physical and financial. They are now getting to the light at the end of the vista; the heaviest of the works on the north bank of the Thames, including a passage under one of the basins of the London Docks, being now practically completed.

One of the heaviest works on the line—Brunel's famous Thames Tunnel, of 1300 ft. long,—was really opened, although not for railway purposes, on the 25th of March, 1843. In 1863 a select committee of the House of Lords on Metropolitan Railway communication reported in favor of the construction of the East London line, as part of an outer circle of railway communication within the Metropolitan District. In the year 1865 the company obtained their Act of Corporation for the construction of a line of about eight miles in all, to form a junction with the Great Eastern Railway at or near Shoreditch to pass thence, principally in tunnel, under the docks at Wapping, and through the Thames Tunnel to Rotherhithe, thence to junctions with the London and Brighton and the South-Eastern railways at their respective stations at Newcross. In December, 1869, the line was opened from the north end of the Thames Tunnel at Wapping to a junction with the Brighton line at Newcross. Other junctions with the lines on the south side are almost complete, and, as already stated, the heavy works between the Wapping shaft and the junction with the Great Eastern are in a very advanced state.

The curves and gradients are favorable, the quickest of the one being on a radius of fifteen chains, and the sharpest of the other a short length of one in sixty. The road is level under the docks, and then rises for a short length to Shadwell Station. The rails are to be double-headed, and of steel, weighing 75 lbs. to the yard.

As may be readily supposed, the heavy works on the north side commenced from the Wapping shaft. These are completed, including the covered way under the dock basin, excepting only a short connection that remains to be excavated to connect the portions of finished

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* From *The Builder*, London, September 18th, 1875.

way; which are of pretty much the same character as the works of the Thames Tunnel, separate "up" and "down" lines, with a 4 ft. 6 in. wall between. The arches are of the ordinary horseshoe shape built with seven rings of brick, and are surrounded with 3 ft. of puddled clay. They have also inverts of brick or concrete. The height of the arches from the rail level to the crown of the arch is 20 ft. and the greatest width 25 ft. In the deep excavations at Wapping 20 ft. of made ground had to be taken up, then 18 feet of gravel, before the London clay was reached. This contained numerous quicksand and pot holes that caused the engineer much trouble.

The property required for the railway between the river and the dock basin was of an inferior character, and a good deal of it was swept away to the improvement of the locality. The most important work here was the underpinning of the workhouse of St. George's-in-the-East. The other important works in underpinning are of one of the London Dock warehouses, and of the piers under it, of the groined arches forming the rum vaults, which were carried down to the level of the railway foundations. Further on the foundations of the Blackwall Railway viaduct were carried down to the London clay, to 50 ft. below the original depth. The preliminary underpinning operations delayed the execution of the other works; but all that remains unfinished now is in active progress. Proceeding northwards from Shadwell station, of which two-thirds of the station works are done, the covered way is nearly all completed to about 50 ft. north of Commercial-road. Between this point and Whitechapel-road the contractors are working at six different points in a short distance of 700 yards.

The retaining walls for the Whitechapel station are nearly completed, and scarcely anything remains to be done but the station. There will be a goods station here on the north side of the main thoroughfare, where the rail level is as near the surface as it can be without altering the levels of important thoroughfares. There will be a goods station at Shadwell also. Between Whitechapel station and the junction with the Great Eastern Railway at Brick-lane, the navvies are at work at five different points. The works here are comparatively light, and there will be no difficulty in completing them within the same time as the works between Wapping and Whitechapel will occupy.

The most interesting engineering exploit on the section is the covered way under the London Dock eastern basin. Operations were carried on, in the first instance, from the surface, and consisted in

dredging trenches in the bottom of the dock until the London clay was reached. The next process was the driving of the piles, clean-squared, and driven as closely jointed as possible. These are of about 14 in. on the side, and about a minimum of 40 ft. long. Fourteen steam pile-drivers were employed in sending them home. There are two rows of coupled piles outwards towards the dock, and one row on the inside towards the railway works. These placed at 4 ft. 6 in. apart inside, and the clay-puddle hard-rammed between the two wooden walls, are the coffer-dams for the protection of the workmen in constructing the covered way under the dock basin.

In addition to the pine forest laid under contribution to provide the piles, another and larger must have been felled and cleared to provide the enormous quantity of timber used in the internal timbering and staging fixed longitudinally, laterally, and with upright supports at the intersections, the spaces between at very short distances. Some idea of the resistant powers that had to be provided in the construction of the works, as well as for their enduring power, may be formed from the statement that the ordinary depth of water in the dock is 21 ft.; under this is a bed of 3 ft. of clay-puddle, followed by 4 ft. 6 in. of brick-work, being the crown of the arch, under which is the covered way, of about 15 ft. clear headway under the dock. In one part of the basin the water communication between one side and the other, and over the railway, has been restored, and one day recently the curious sight presented itself of several large merchant ships,—the *Raby Castle* and the *Victoria*, of London, among others,—lying berthed immediately over the railway, and the large first-class clipper *Lady Macdonald*, outward bound, crossing over it at right angles.

In the construction of these exceptionally heavy works at such low levels, of 50 ft. to 60 ft. below Trinity datum line, powerful mechanical appliances have been necessary, that have included twelve pumping-engines, working night and day; three of these, of 56-horse power nominal, employed at the London Docks, are equal to lifting 50 ft., 8,000 gallons per minute. The whole of the water pumped is from the Thames, or from springs, not a drop percolating from the docks through the finished works. A large number of powerful steam cranes have also been employed for lifting the excavated earth from the workings. Recently a million of bricks have been used, and 600 tons of Portland cement per week. besides a large quantity of blue lias lime. The large quantity of puddled-clay required for the works has been

brought to the ground in barges, much of it from the neighborhood of Rochester. The London clay is totally unsuited for puddling.

The engineering works of the East London line have been designed by Sir John Hawkshaw, as engineer-in-chief, Mr. W. Hunt superintending the execution of the works as resident engineer. The most serious mishap that has occurred since the works were commenced was in connection with the first dock coffer-dam. Delay in finishing the line, and the loss of human life and of money, would have been prevented, it is believed, if the plans for these works of Sir John Hawkshaw had not been unwisely interfered with. Mr. Thomas is the contractor.

The completion of the East London Railway will supply the missing link in the connection between railways separated by the Thames, and must greatly facilitate intercourse between Middlesex and Essex, and Kent, Surrey, and Sussex; it will give a stimulus to building operations; it will afford the shortest and the only unbroken route for minerals and merchandise between the northern and southern counties and the southern shipping ports, saving in addition to the advantage of continuity, five miles in distance. It will have no opposition to encounter either from rival lines, steamboats, tramways, or omnibuses, to which other metropolitan lines have to submit. It will also command a larger proportion of through goods and passenger traffic than the lines referred to. It seems likely to secure a considerable traffic from the Foreign Cattle Market at Deptford, and of timber trade from the Commercial Docks, by a short branch running into these docks. It will also have a siding and station at the London Docks, from which merchandise may be carried to and from all parts of the United Kingdom without transhipment. It will furnish the shortest route to the densely-populous districts in the east of London for the Crystal Palace, Hastings, Eastbourne, Brighton, and good routes to Ramsgate. Margate, and Dover.

Costly although the East London line has been,—500,000*l.* per mile,—its cost is much lower than that of any other metropolitan lines, some of which have cost from 850,000*l.* to more than 1,000,000*l.* per mile. The average distance traveled by the passengers on these lines, such as the Metropolitan, the Metropolitan District, and the Charing-cross, is not more, probably, than a mile and a half, whereas on the East London line the average distance traveled is unlikely to be less than four miles. The East London will be worked by the Brighton Company under agreement.

THE PRESENT STATE OF THE CORNISH ENGINE.*

It is well known to engineers that the Cornish Engine in Cornwall itself has much retrograded in economy the past 30 years, and, the following remarks of the editor and correspondents of the *Mining Journal*, coming from witnesses thoroughly cognizant with the present condition of the engine, seem worthy of reproduction in America.

The editor of the *Journal* says (in the paper of the 18th):

A thoroughly practical method of arousing Cornish miners from that distressing lethargy which has done so much to add to the hardships resulting from the long period of depression, happily now nearly past, has been adopted by Mr. Basset, of Tehidy, who proposes a series of handsome prizes, to be awarded upon results actually produced, and who has himself contributed a large amount to the prize fund.

In conducting mechanical processes it is an admitted fact that results once obtained can be obtained again, whence it follows that inasmuch as with the engine at the United Mines a duty of 128,000,000 has been reached, that is to say every pound of coal consumed has been made to raise more than 1,140,000 lbs. weight 1 foot high, the average duty of Cornish engines during the first half of the present year was but 47,000,000, so that each pound of coal consumed has raised only 420,000 lbs. weight 1 foot high. To put the case in still more simple form, the Cornish engines during the first six months of 1875 did with the same consumption of coal less than one-third the work which was actually done with the United Mines engine half a century ago. But this is not all, the Cornish engines were doing 10 per cent. more work in 1870 than in 1875, and they were doing 45 per cent. more work in 1842 than in 1875. The retrogression has thus been as constant as it is alarming, and reflects the utmost possible discredit upon both Cornish mine managers and Cornish enginemen. It would appear that a class of writing managers have taken the place of the practical managers of former years, and that these writing managers have not followed the excellent example of the German and American by acquiring technical knowledge likely to be useful to them in their business. Yet that Cornishmen are not without the constitution and character which make good miners is shown by the high positions they attain in foreign countries, but the general aversion to progress which prevades the county seems to deprive

*Extracted from the *Mining Journal*, London, September 18th and 25th, 1875.

Cornwall of her best miners, and leave none but the incompetent and uneducated to manage Cornish mines. The prizes suggested by Mr. Basset will, it may be hoped, create a spirit of emulation which will be alike beneficial to the miners themselves and to the adventurers whose money is sunk in mines of the country.

These remarks have called forth the following reply (in the paper of the 28th) from an "*engineer*" at Redruth. Referring to the quotation by the editor, of the high duty reached by Taylor's engine, United Mines, in 1842, to show the apparent retrogression in the Cornish engine since that period, the writer proceeds:

This comparison is now become of frequent occurrence, but no notice whatever seems to be taken of the different conditions under which Cornish engines, as a rule, are now worked, and at that period were worked, or of the age of the engines from which the present average is taken.

A glance at the duty paper of the former period will show that the engine-shafts were then nearly all perpendicular (at the present day we have *one*, against *seventeen* in 1842,) and where more than an average duty was reached, the engines were moderately loaded so that the friction was reduced to a minimum, and enabled a high rate of expansion to be carried out. The very opposite is the case in the present day, owing to the system of mining pursued of late years—sinking the shafts on the irregular course of the lodes, for sufficient and probably satisfactory reasons—but at an increased consumption of coal, friction of necessity being considerably increased, and a high rate of expansion becoming impossible. Compare, for example, Taylor's in 1842, and Pelly's, Crenver and Abraham, in 1875. Taylor's had a perpendicular shaft 200 fms. deep, with a load of 12 lbs. per square inch, working five strokes per minute; and a new machine (Pelly's) has only 164 fms. perpendicular, 125 fms. diagonal on the corse of the lode, loaded 25 lbs. per square inch, and is worked upwards of 20 strokes. The conditions are so dissimilar that no comparison can be drawn; the friction of the latter is considerably increased, and a low rate of expansion can only be reached; that there should be more than 50 per cent. difference in the duty under these circumstances cannot, therefore, be wondered at. But it must not be supposed that everything went smooth with Taylor's engine; this high rate of expansion resulted in a serious breakage, and from that day to this such a rate of expansion has not been attempted, neither do I think it would now be recommended by any engineer.

This is not the only reason that brings down the average. The average of the present day is in three instances made up of engines at work in 1842—Botallack, Carn Brea, and East Pool: their average duty in 1842 was 58 mills, now 39, but their average lode has increased from 12 to 17 lbs. per square inch; they have 140 fms. additional flat-rods, and this after 33 years' additional wear and tear.

Taylor's engine was a new one, working under exceptionally favorable circumstances, but the average of the present day include, the above-named engines (one of them has been at work 53 years,) and others working under the conditions named.

Let those who condemn the Cornish engine recollect that the present average duty of Cornish engines includes amongst them one which has been at work continuously on one shaft upwards of *fifty* years.

We extract from another part of the same issue of the *Mining Journal*, the following weekly statement, which is that referred to by the "*engineer*."

The number of pumping-engines reported for August is 16. They have consumed 1819 tons of coal, and lifted 9,100,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 46,600,000 lbs., lifted 1 ft. high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty:—

Crenver and Wheal Abraham	—Sturt's 90 in.	Millions	50·1
Ditto ditto	—Pelly's 80 in.		52·7
Ditto ditto	—Willyams' 70 in.		55·6
Dolcoath—85 in.			55·5
West Basset—Thomas' 60 in			48·3
West Wheal Frances—58 in.			52·2

It must be admitted from the engineering-commercial point of view that the attainment of so high accomplishment, as was indicated between 1830 and 1845 in Cornwall, may have been effected at greater cost in other ways than what was saved in coal. Selected coal, no breize, extra attention, extra risks of breakage in short cutting off, slow running, which meant large engines at greater primary outlay and interest, all these are items of constant expense.

The profitable limit of performance was undoubtedly surpassed in the emulation. If however it can be shown by a new competition that the loss has even partly been the result of negligence, rather than by overestimation, a desirable result will have been reached.

With the best of engines and with 128 millions of duty (English standard,) there is yet left over nine-tenths of heat of the fuel to account for, but it is only by keeping all that has been gained, that improvement can be expected.

GAS WORKS ENGINEERING.

By Robert Briggs, Civil Engineer.

Holder and Tank for the Citizens' Gas Light Company, Buffalo, N. Y.

[Continued from Vol. lxx, page 252.]

The time in which the tank was to have been completed and possession given to the iron workmen having expired, the writer visited Buffalo early in the month of October, and then made the first and only inspection of the tank work. The lines of the ground and those for laying out the tank and its column piers had been given by a local engineer, Mr. Davies, who was indeed amply competent to have had charge of the construction under the specification, but no further duty than the setting out was devolved upon him by the company, the contractor having been permitted to work in his own way with little occasional supervision from some of the directors.

The ground proved to be a fill of ashes and rubbish of 10 to 12 feet depth, which had been made on a loose alluvial deposit of 5 to 6 feet, and then came 2 to 5 feet in places of compact alluvial, somewhat clayey, to natural surface of rock. The surface of this rock had at one time been the bed of the Lake (or rather of the entrance of Niagara River) and rapids must have existed here; the location of the works being about 800 or 900 feet from present shore of the lake. The rock bed was very irregular and eroded by former action of water and ice, and at some places three or four feet of rock were removed to give the proper depth at the side of the tank. Elsewhere, in the immediate vicinity where the rock had been uncovered, fissures had been found, and blasting the surface had discovered channels, which were supplied with water from the lake (the surface of which was 5 or 6 feet above the level of the bottom of the tank) but in this place, by great good fortune, no such supply of water was disclosed.

There were, however, several springs of no great moment which broke out through the foot of the cone of alluvium left in the centre of the tank.

The provisions specifying for under drainage of the bottom had been neglected, and about 70 to 100 square feet of the paved bottom had been lifted by the force of the springs.

It was said that the walls of the tank all around, had their foundations on the rock itself, having been carried about 2 to 5 feet at one side below the specified depth for the purpose.

The bank of earth had been improperly shored for the loose material, and extensive caves had ensued, involving the loss of the old retaining wall and the shed, which the additional specification required to be supported. This loss, however, was inconsiderable in amount.

Much delay had followed the caving, and also from the non-performance of some sub-contract for excavation, and the brick work was three weeks behind. Three weeks *after* November 30th at Buffalo, is a serious matter in outside iron work.

Considering the fact that the loose material was only about 15 feet deep, on the average (both fill and soil) it would have been as well to have dug to a slope of one to one at once, and straightened up the sides of the cut, back of the wall, and filled solid in a back trench thus made after completion of the wall.

There had been a loss of lines incident to the cave, the pier stakes having been unprotected, and a second setting out by the surveyor had been made to correct the shifted piers. The back filling properly had been entirely neglected, and after the *rubbish* had been deposited 10 or 12 feet high, it was *puddled* by running in a stream of water by a hose. No iron ties were used, the contractor not deeming them necessary. Perhaps the most radical departure from good tank construction laid in leaving a cart-way gap at one place, which was not filled up until after the wall was to its height generally. Nothing but the rock foundation of the wall and the looseness of the back fill saved the tank in good shape against such defects in erection.

The bricks were very good, sound, straight, and hard burnt, but the mortar was made from a species of hydraulic lime, which had little or no quality of *setting*, and only hardened under water in time. It was said to become solid in two or three years, at the end of which time it had the character of our American natural cement of no very high grade.

This condition of the work becoming known to the writer, he at once called the attention of the officers of the company to it, and immediate steps were taken by them, to at least ameliorate, some of the errors. Many of the defects were beyond correction, but much was done to bring the work more nearly to conform to the requirements

of the specification. In one regard, attention is called to what was done: the bottom of the tank was cut through in channels from boiling spring to boiling spring (about 6 or 7 places existed when the water boiled an inch or two high amongst the bricks) and under drains formed to lead to a well at the edge of the bottom. This well, as specified, had a closure or diaphragm plate, one foot from the top, with a valve opening upwards in the middle. The drains *discharged under the plate*, and when the head of the water was strong enough, it lifted the valve. This it did without bursting up the bottom.

It follows from this system of drainage that all the springs can, with much freedom, enter the tank as long as the head of the water within the tank does not close the valve, but when the head of water within the tank is great enough to close the valve, no water can run out of it. To make this proposition more clearly comprehended, let it be supposed that the springs in the bottom of a twenty feet deep tank would find their level and fill it three feet in depth with water; now these springs must evidently have an overflow somewhere (in this case they had the lake 800 feet distant) and any attempt to fill in water above the level would result in its discharging at the the overflow of the springs. The water of the tank would thus empty to a certain level, through the same passages that previously had supplied it.

This description has been made so particular in order to convey the idea of what should be avoided in building a tank. With 25 years' experience in construction of gas works, the writer does not think that one tank out of three which he has had to do with has proved satisfactory. It is with great difficulty that a local house bricklayer can be induced to do hydraulic work. The few men who know how, and have done, government or dock work are so under-bid by those who contract to build, that their opportunities for employment by a gas company are very small. There are three things needed for a tight tank for a gas holder: a good specification, a competent engineer, and a number of skilled bricklayers. The willingness to pay for good work on the part of the gas company, and the honesty of the contractor, are conditions precedent to the construction.

At about four o'clock on Sunday afternoon, December 4th, a telegram was handed to me informing me that the holder had collapsed, and asking an immediate personal visit to Buffalo. At seven P. M. I was on the train for Buffalo, reaching that place at two P. M. on Monday.

An immediate examination of the wreck disclosed the holder with both sections down upon the anchor blocks, and the crown of the inner section introverted on three-quarters of the circle with the centre down some two and a half feet. The sheets appeared unhurt, but wrinkled, folded and buckled, the whole resembling the top view of a demolished umbrella. The man-hole plate was removed, and the water level was about four feet below the curb. A stream of water was leaking out of one of the bank walls and a small steam pump was also removing the water from the tank. And the thermometer was about 20° above zero, with a west wind that cut like a knife. A gang of men were removing the retaining wall at the piers on Georgia street.

An enquiry into the accident revealed that the tank had been filled with water some days, and the holder had been tested on Friday. It had proved excellently, had been blown out twice or more to work out the air, and the inner section had been elevated nearly or quite to full height. (It is not recollected if the outer section had cupped.) As the holder capacity was much needed it had been put into regular work by the gas company. Meanwhile, on Saturday, a leakage was observed, which was found to proceed from a crack in the tank at a column foundation near Georgia Street. After its discovery, the crack rapidly opened, and it was decided to pump down the water five feet or so, (to the level of the streets outside) and a small pump was put on to remove the water. At this junction it was also decided to discharge the gas once more (as gas was making very fast at the benches) to eliminate the last trace of air from the holder. The inner section was blown off by loosening the man-hole plate, until it rested on the blocks, when the man-hole plate was replaced tightly. All this was done without consultation with the foreman of the iron work, who had left the holder 8 feet or more out and going up at four P. M. on Saturday. Having thus arranged the holder, the gas inlet and outlet had been allowed to remain cut off, with the leakage of the tank and the action of the pump (which continued running during the night) until at three to four A. M. on Sunday, when the crown collapsed with almost explosive violence. Residents of dwellings 600 to 800 feet distant felt the vibration and shock of the catastrophe.

From the rate of discharge of water from the tank, it is probable that 12″ to 18″ of water pressure was accumulated before the crown yielded and 180 to 270 tons pressure were distributed upon this crown.

The gas was thoroughly displaced when I reached the holder, the cold air outside had descended to the level of the water, and expelled the last trace by diffusion, and an internal inspection with lights was possible. An examination from a float exhibited 13 of the 16 main rafters broken in the middle of their length, at the scarfed joint, where the queen posts attach, the breakage being merely the *shearing off* of the scarf piece bolts, (4 $\frac{5}{8}$ bolts); the parting of all the main tie rods, either at the king post in the thread portion, or by shearing off the bolt at the gusset next the legs (two of the gussets were torn away from all their bolts); the upsetting, but not shearing off, of all the centre plate rafter bolts and the crippling and springing of many, in fact most of the flat purlins.

The most striking evidence of the force expended was shown at the centre pier. It was a pyramidal pier 3′ 6″ square at the top, and spreading $1\frac{1}{2}$ inches in 12 inches on all sides; not very soundly built, and with mortar scarcely stiffened in its set; but it was massive, and it was capped by a sound block of Medina stone 3′ 6″ square by about 8 inches thick. The stone would be called good building material anywhere. The stone was cracked to small pieces, and the brick pier below it demolished and also crushed, many of the bricks being broken in fragments as well as displaced. The fracture of the pier was diagonal, as the three tie rods (and rafters) which were uninjured, had dragged over the foot of the king post about 12 inches to one side.

It did not seem that any serious injury had been done to the internal iron work structure.

Finding so good appearance within, a new and close examination of the sheets of the crown on the outside were made. Original good iron, the accurate punching of a multiple punch (which punched sixty holes at once, together with accurate laying out of sheets), and the avoidance of any reaming or stretching of holes when riveting, had produced so good work that no breakage or injury was apparent. Not a seam showed signs of a crack or opening, and although the buckles were (some of them) two feet or more in depth, and very short, (five to eight feet between crests of the waves) no bent plate could be found. With all this, it is proper to assert that the appearance of the top of the crown to an engineer or practical mechanic, without close examination, was truly hopeless for restoration; and

some opinions of very positive character had been given the Gas Company previous to my arrival in the city.

The result of the examination in my own mind, was to advise the pumping out of the tank as quickly as possible, before a snowfall, then to be expected daily, should load the crown, and cause further injury. And after the emptying of the tank to the level of about one foot above the anchor-blocks, to enter the holder with a gang of men, have it closed, and blown up with air; and when the crown should be reverted to its original place by the pressure to straighten and shore up the rafters one by one; to block up the king post from the centre, and having thus replaced the crown, relieve it of the air pressure, and letting out the gang of men, then proceed at leisure to repair the sheared and broken bolts.

The proposition was at once accepted, but simple as the measure, and perfectly safe the method, it was found merely impossible to impress either upon the workmen. Divers who were practiced in hours of work in the water at the bottom of Lake Erie, objected to the *risk* in this immense reservoir of 130,000 cubic feet of air. Carpenters feared the pressure, although they were assured they might be exposed to greater difference any summer's day. Gas workmen could think of nothing but explosion. And after reasoning with several, the writer found the only alternative was to remain in Buffalo and lead himself.

An examination of the tank showed three cracks from the top of the wall downwards, caused by insufficient backing. Two of these cracks followed the line of junction of column piers, and the third was intermediate (about half-way) between the two piers. In accordance with the advice of the writer, the backing at this place was excavated, and the earth removed to the very bottom of the tank wall, and a revetment pier of 8 feet projection and 3 feet width, behind the wall at the base, with a batter of $1\frac{1}{2}$ to 12 towards the tank as it came up, was built. From this revetment pier, two wings of brickwork were built to abut the column piers at their groin with the tank wall. From much experience, it can be said that the attempt to make a tank wall tight by pointing or grouting a crack, is nearly always a failure, and that all efforts short of revetment piers are so nearly direct waste of money, that no engineer is justified in advising them. A further allusion to the tank will be found in the report on the subject to the company, hereinafter appended.

Of course, this work of reparation of the tank had to be done under temporary cover, and also, of course, strict regulation was had as to walking on the crown in its precarious state.

The means for supply of air for the proposed operation, at the works of Buffalo Gaslight Company, were singularly favorable. The company had been making a partial hydro-carbon gas from anthracite coal and super-heated steam by means of a generator of the type introduced into this country forty years since by Faber du faur, (which gas was afterwards carburetted by benzine vapor *fixed* in it by passage through low heated retorts.) The generator was supplied by air by a Blake air pump having a capacity of 500 to 600 cubic feet of air per minute, and it was convenient to take the air by a line of 3-inch wrought iron pipes to the holder; there was an opening on the delivery of the air pump available for this purpose.

If, however, it had happened, that no such supply of air were at hand, it would have been feasible by means of four to six ordinary smith's bellows and a line of soldered tin pipe to have air under suitable pressure at the rate of 60 to 90 cubic feet per minute with, of course, some disadvantage in time. For the engine pump would lift the holder one foot in ten minutes, while the suggested bellows would have taken an hour and a half for the same result.

The preliminaries of pipe line, and all other steps essential to the success of the scheme were effected in readiness.

It was late on Thursday afternoon before the water in the tank was low enough to expose sufficient part of the conical bottom to work upon. At this time, the water was $3\frac{1}{2}$ to 4 feet deep at the sides.

There had been taken into the holder and deposited about the centre of the cone, during the day, thirty lengths of hemlock scantling, $3'' \times 6'' \times 22'$, with other joists and boards for scaffolding, together with a pile of blocking timber, tools, etc., and at about eight o'clock, after several callings of the roll, ten out of twelve men were found.

Some experiments demonstrated that conversation could not be carried on, and a set of signals had been arranged. The order of repetition of raps on the inside of crown, was made into a telegraphic communication between *the ins* and *the outs*. Of course, it had to be very simple, as the occasion did not demand an extensive code. The inside of the holder was illuminated by forty or fifty 4-inch candles, secured to the rods of the crown by bits of copper wire. After calling roll, everything being ready, the foreman of the

gas works volunteering to act as outside director, the gang of men descended into the abyss, and the man-hole was bolted down. A little delay ensued by one man's having gone home (near by) to inform his family of his undertaking, and by his declining to join in the risk after his return, and the missing men came to the holder, one joining, and the other, after listening a few moments at the man-hole, and hearing no sound, solemnly pronounced them "all dead," and went his own way, above ground, in fear!

The ladders having been displaced, and the men put in such position that the fall of rods or rafters might not hurt them (only one end of one rod fell down), the proper signal was given, and the pump was started. In about a minute, an evident noise of shaking sheet iron was heard; in five minutes the king post was free from its centre pier, and the resonance of sheets was like distant theatrical thunder. In ten minutes the whole crown was inflated, and in about twelve minutes the outside director signaled that the inner section was three inches afloat from the anchor-blocks, and that he had stopped the air pump, as agreed upon. On the inside, the centre pier was leveled off, and the king post blocked up and wedged, when, at the signal, the air plug was opened, the holder dropped upon the anchors, and the discharge of air stopped, thus thrusting up the centre, and removing part of the *apple* shape. (It was supposed, when this was done, that three inches would have been enough, but subsequently, it appeared that the holder should have been lifted about nine inches, and then dropped, to have effected the end entirely).

The thirteen broken-backed rafters, were then found to be depressed in their middles (half way from edge to centre) from 2 to 3½ feet (except one which was detached from its position, and dropped 5 or 6 feet.) The restoration was exceedingly easy; one by one they were quick-shored and spur-shored, by the 22 feet scantling and blocking, offering some resistance and squirming as they passed the toggel line. They were shored up to the apparent proper curve without any attempt at exactness. As the work proceeded, the king post was straightened up, and finally lifted off from its blocking. When this occurred, a signal was made, and the section was raised again, the shores being watched to see that they were not loosened, and four inches of blocking more inserted under the king post, when the section was, by signal, again anchored. After this, some of the rafters

had to be further shored up. The whole work of shoring up the thirteen rafters occupied four and a half hours.

The work had been done in the night in preference, so as to ensure the undisturbed attention of the external requirements. It was an intensely cold night outside, but a few degrees above zero, and the clear sky gave a radiation through the thin plates of the crown, yet within the holder it was about 40 degrees and only chilly, and at the last smoky from candle smoke, but otherwise not uncomfortable.

At two o'clock in the morning, the signal was given, the man-hole was loosened and removed, and the workmen emerged. The exterior of the crown showed that the gradual lifting of the rafters had again elevated the whole roof, leaving the king post still down about six inches, and of course the sheets were not free from buckles, and the apple shape was very evident. As had been indicated by appearances, the sheets and joints proved unhurt and tight, not a particle of leakage of air having accompanied the raising of the crown, nor did any subsequent defect in this respect develop itself.

Having thus placed the holder in condition to be repaired, the erection of a temporary scaffold near the sides, and the testing and replacing of the injured parts of the internal framing was easy. In fact, a complete restoration was made in less than a week afterwards, at a cost of not to exceed $300 for the iron work, and the holder was ready for use again by the 20th of December, and was in use on the completion of the tank repairs, shortly after. It would be impossible to find any signs of injury from this accident at this time.

After completion of the holder, some questions from the officers of the Buffalo Gaslight Company led to the following report, which is here inserted as a means of conveying some information upon strength of tanks not accessible in similar form elsewhere.

Philadelphia, January 29th, 1875.

J. M. Vought, Esq.,

Secretary Citizens' Gas Co., Buffalo,

My Dear Sir:—In accordance with your request that "I should write you in full upon the failure of your tank, and state whether the specifications were carried out, and if not, whether that was the cause of the failure." I make the following reply: Referring to the specifications: *The sides of the excavation must be carefully shored to pre-*

vent caving; and in case of a slip, the entire mass of broken earth must be removed, and a new fill puddled and rammed in the back of the wall.

The banks were not properly shored—there was a slip—the earth was not replaced by puddling and ramming as prescribed. The prescription of the specification relative to springy bottom was conformed to and the bottom is consequently tight. "*The proper care was* not *taken in setting out* or preserving *the location of column foundations,*" and much additional stonework was needed in the retaining walls to remedy the difficulty.

"*There will be laid in each course of mortar on the flat, each ten courses of bricks,* 3 *or* 4 *strips of hoop iron,* 1¼ *ins.* × *No.* 20 × 8 *to* 10 *feet lengths, the ends overlapping about two feet, to make the bond of the wall.*" This requirement calls for 11 courses of hoop iron strips 1¼″ × No. 20, and 3½ strips to each course; the total weight of iron called for was only 2100 lbs., and the least section of all the bands together at any vertical section of the tank wall would have been equal to 1·69 square inches of solid iron. As expressed in the specification, this iron was only "*to make the bond of the wall.*" It was not supposed to be strong enough to form a hoop and sustain the pressure of water independent of the strength of the wall as masonry, or of its support by earth backing.

The total pressure of water tending to burst the tank walls at any place was, say 93′ 6″ (or centre of wall) diameter multiplied by 22′ 8″ depth of water, multiplied by ½ the depth of water, multiplied by the weight of a cubic foot of water (62·4 lbs.) = 750,000 lbs. (nearly.) Now the foundation of the wall was on solid rock, and the weight of brickwork alone was sufficient to warrant the assumption that no splitting would have occurred at the bottom. And the application of this force of 750,000 lbs. can be taken at the centre of pressure (⅓ the depth from the bottom) with the bottom practically unyielding. This assumption is equivalent to the application of 500,000 lbs. uniformly on the sides of the tank.

Hoop iron of No. 20 (·035 inches) thickness has the highest tensile strength allotted to wrought iron, it is hard rolled and nearly unyielding to the point of rupture, and can be fairly assumed at standing a tension of 60,000 lbs. per square inch of section, before rupture. Assuming *one-half* this tensile strength, the section of 1·69 square inches gives 50,000 lbs. as absolute strength of the hoops.

The adhesion of mortar to the surface of each hoop is quite equal to its assumed tensile strain. The weakest place in the hoop is, of course, the middle of its length, and it can be estimated as subjected to strain in opposite directions from that point. The sectional area of the hoop equals $1\frac{1}{4}'' \times \cdot 035''$ or ·04375 square inches; multiplying this by 30,000 lbs. tensile strain, and the total tensile strain is found to be 1312 lbs. The surface of either half of a ten-foot strip is $2\frac{1}{2}'' \times 5'\ 0'' = 1 \cdot 04$ square feet, or equal to 1300 lbs. adhesion to each foot of surface of the hoop.

These figures show the strength of the hoop ties as specified to have been about one-tenth that needed, if they were to have been the sole reliance against this bursting strain on the walls. The specification requires "*that the mortar to be used for bricklaying, concrete or cementing, must be one part of new hydraulic cement, of approved quality, and two parts of sharp sand, and must be used as fast as made; any set mortar must be rejected and not tempered into new mortar.*"

The material used to make mortar was not cement at all, but was hydraulic lime; as to the conformity in preparation to the specification, I cannot testify; but from inspection of the crushed centre pier, and at other parts of the work, I can say, that the mortar is only a fair building mortar, suited to make joints of brick or stone work of buildings or piers where the usual disproportion of material as regards loads superimposed upon it, is followed. It did possess a great advantage over common lime for water work, in having a degree of insolubility, and possibly in the same course of time which is requisite for good quick lime mortar to become hard, in construction above ground, this hydraulic lime mortar may harden under water; but as a mortar to be used in *cistern or tank work*, having the quality of quick setting and of immediate *tensile* strength, it by no means satisfies the conditions of the contract.

Unless this deviation from the requirements of the specification was made with the full consent and *approval* of the Gas Company, or their Engineer, the contractor should be fully held for the consequences. Admitting that the walls of the tank were built of specified thicknesses, and with specified quality of bricks, which so far as my observation went, were the facts; their strength as masonry, on the supposition that Rosendale cement had been used, can now be properly

considered. As in the case of the hoop bands, the bottom can be taken as unyielding, and the mass of the walls adhering to it as capable of sustaining one-third of the bursting strain, leaving 500,000 lbs. tension as the total load at any vertical section of the tank walls to be resisted. The walls have very nearly 50 square feet of cross section, and the consequent tension per square foot of brick work is 10,000 lbs. = (70 lbs. per square inch.)

The rupture of a mass of brick work can be estimated (if perfectly sound and of uniform strength) in either of the two following ways:—

First, on a plane of rupture at the ends of half the bricks, and across (through) the other half. A square foot of cross section of brick work (of Buffalo size) is 3 courses wide by 5 courses high, the bricks are $7\frac{3}{4}$ inches long × $3\frac{3}{4}$ inches wide × 2 inches thick, thus,

$7\frac{1}{2}$ ends to break, $3\frac{3}{4} \times 2 =$. $52\frac{1}{2}$ square inches.
$7\frac{1}{2}$ " " separate at the joint,
$3\frac{3}{4} \times 2 =$ . . $52\frac{1}{2}$ square inches.
Surface of mortar = . $39 = 144$ "

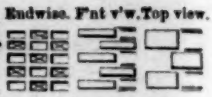
Bricks of low quality have, at least, 150 lbs. tensile strength per square inch, (all authorities give 150 to 300 lbs.) The adherence of Rosendale cement mortar to bricks after one month's setting is given by Gilmore to be, *at least*, 12 lbs. per square inch. The tenacity of Rosendale cement mortar laid out of water one month is deduced by Gilmore as fully equal to 50 lbs. per square inch [Grant. Inst. C.E., London, 1865, gives 100 for Portland average of 370 trials] and we have from above,

$7\frac{1}{2}$ ends to break = $52\frac{1}{2}$ @ 150 = 7875
$7\frac{1}{2}$ " " = $52\frac{1}{2}$ @ 12 = 630
Surface of mortar = 39 @ 50 = 1950 = 10,475 lbs. per sq. ft.

For my own part I am decidedly of opinion that the 630 lbs. of adhesion of ends deducted from Gilmore's experiments are not over one-third the real strength (Gilmore's mode of test was very unfair), and I am confident that the least strength of a square foot of solid brick work in mortar of one part Rosendale cement to two of clear sand is quite 12,000 lbs. per square foot.

The second method of computing the rupture is to assume that it follows the joint, and does not part any of the bricks which have an average of 3 times the strength of the mortar.

In the top view, as the wall averaged but $3\frac{1}{2}$ bricks wide, there were but 6 joints for the 7 half bricks, or $2\frac{3}{7}$ joints to each foot of width. If the bricks were laid with perfect accuracy, they would have 4 in. laps, but it is fair to take the laps at not over 3 inches in practice, and thus is found:



15 ends of bricks to separate ($\times 3\frac{3}{4} \times 2$) =	105 sq. in.	@ 12 =	1260 lbs.
Surface of mortar on end section =	39 "	@ 50 =	1950 "
$5 \times 3'' \times 12''$ flat joints to break =	180 "	@ 50 =	9000 "
$2\frac{3}{7} \times 3 \times 12$ edge " " " =	82 "	@ 50 =	4100 "
			16,310 lbs.

Either of these computations show an excess of strength over the requirement, and that with the hoop iron to prevent check cracks and to strengthen the wall, where the header courses were used; the tank could have carried the weight of water without backing of earth. It was certainly amply strong *with* the required earth work or retaining walls to support it. But all this supposition rests upon "*Hydraulic cement of approved quality*," of which I should consider Rosendale as quite low as a standard. I do not believe the hydraulic lime mortar used, has at this time, a tensile strength of ten pounds per square inch.

"*Behind the walls of the tank there shall be filled in, rammed and puddled, suitable material to form a water-tight solid bank.*" I saw no ramming—the dumping of loose fill of rubbish into water by no means answered the requirement—the material used, to my view, was not suitable for filling, nor was any water-tight clay used. Considering the mortar employed and the omission of the hoop iron ties, the only reliance for the construction was the backing. If the backing had been properly done—according to the specification in all respects—it is my opinion that the defective brick work would have had adequate support, and no accident would have occurred. It is fair to admit, however, that while I consider the earth backing as equally imperfect with the brick masonry, the ruptures apparent at this time, have not happened when earth filling only was prescribed.

"*There shall be built on the line of the lot on Court Street and on Georgia Street, two retaining walls in stone masonry, each about 32 feet in length (exclusive of wings at either end, which may be needed to hold the bank.) . . . Below level of side-walk, these retaining*

walls are to have a footing on the natural ground (under soil) and at least 3 *feet under side-walk level, which footing shall spread two inches in every foot of depth. These retaining walls shall be built up solid against the brick walls of the tank, ... at the end of the retaining walls will be required wing walls from* 18 *inches to* 2 *feet in thickness, with foundations at least* 3 *feet below side-walk level, suitably coped. The excavation for these walls will be made to such depth as may be directed by the Engineer of Gas Company," etc., etc.*

The immediate cause of the failure of the tank laid in the non-conformity of one of these retaining walls (that on Georgia Street) with the specification as above quoted. [As to the other retaining wall, on Court Street, or the remainder on Georgia Street, I cannot say whether they were improperly constructed or not.] At the wall on Georgia Street, between two of the column piers, the tank wall went out with three cracks, one at each pier, and a third midway between; the cracks opening $\frac{1}{16}$ to $\frac{1}{8}$ inch at the top and extending about 12 feet downward.

The examination which followed, showed that the wall in place of having a footing spread two inches in width for each foot of depth below level of side-walk, which would have given 3 feet of external batter, had the foundation been carried down to the very bottom of the tank, was founded upon a triangular mass of concrete, which concrete had been substituted for the rammed earth specified to be used in case of a step. In consequence of neglect of the lines, the column foundations of the tank had been twisted about 8 or 10 feet out of proper position, and the retaining wall which should have been nearly parallel and of equal thickness, had become, say $3\frac{1}{2}$ to 4 feet wide at one column pier, and 8 to 10 feet wide at the next.

The triangular mass of stone work consequently overhung any foundation or footing at one place 5 or 6 feet, and in no one place had the wall what could be designated as a proper footing, leveled suitably on natural ground, or its specified substitute. On removal of the wall for reconstruction, it was found to have fallen away 2 to 3 inches in the widest places, with a pocket of 12 or 15 feet in length, where the wall had left the brick sides of the tank. This subsidence had evidently occurred whilst the wall was being built, and not afterwards; for the stone work had been gathered over against the tank wall. The retaining wall thus built, actually prevented the earth from sup-

porting the sides of the tank and became a point of weakness, instead of strength.

The wing walls were also improperly built; in place of being independent from the retaining walls, they were bonded into them and the foundations of these wing walls were also tied into the retaining walls. This bonding of walls, where footings do not coincide, is a serious injury to both; there should have been a plumb joint between the walls. I have enumerated the essential points of deviation by the builder of the tank from the specification, any one of which was fraught with danger to its stability, but the pre-eminent one is, "*These retaining walls shall be built up solid against the brick walls of the tank.*" With the use of inferior mortar and in the absence of the iron tie-bands, the accident was invited at this point and occurred *here.*

The specification reads: "*The Gas Company will hold the contractor responsible for the cost of reconstruction and for damages which may follow if the workmanship and material does not conform to this specification, whether noticed by the inspector or not; but will assume full responsibility for the tightness of the tank if the work is as specified.*"

The deviation from the specification in these regards named by me, I believe to have been one and all intentional by the contractor, with full knowledge and assumption of the risk, and they were done for the purpose of reducing (to himself) the cost of the work. In some of the deviations, he may possibly have had a color of permission or direction, but if so, I am confident such assent or authority was only granted on the assurance by the contractor that the changed construction or material was equally or sufficiently good.

The question of damages resulting to the Gas Company resolve themselves into several points.

First. The extra cost of stone work, incurred in buttresses because of twisting the column foundations after laying out by the Gas Company's Engineer. This is estimatable by your engineer.

Second.—A. The cost of repairing the break, including the pumping out and refilling of the tank, earth work, stone work or brick work, engineering, or other expenses. B.—The injury done to the holder, which was sucked in by the escape of water from the tank. C.—The loss to the company resulting from the supplying of the district by the Buffalo Gas Company.

Third.—A. The probable cost or equitable valuation of cost of reconstructing the next piece of retaining walls on Georgia Street, where another leak has already developed. B.—The probable cost of other reconstruction on Court Street side.

Fourth. The impaired value of the tank in its present state. This can be made up as follows: A.—The money value of material and workmanship improperly done. The saving on earth work; this value can be made up by your engineer. The saving in mortar and laying; this is also a matter of engineer's estimate for quantity; the saving of hoop iron (about one ton) and the cost of laying it, say one hundred dollars, ($100.) B.—The consequential injury; built as your tank has been, I should feel no security that it would remain tight from one week's end to another; by buttressing it, as the broken segment has been buttressed, at each of the eight spaces between columns, it could be made reliable. The cost of constructing this buttress thus becomes a measure of value of *reconstruction* to make the whole equivalent to its *specified* construction.

In settling this whole question, if the company feel any especial compassion towards the contractor, possibly they might authorize a settlement which would assume a part of the risk of future failure. It is clear now that one buttress more will be indispensable, how many others *may* be demanded, or their cost, taken as security against further accident could be determined by the Gas Company.

The view I have here given, will, I am confident, stand the test of legal scrutiny or of a settlement under an arbitration to engineers. The company had a right to receive as good a tank at the hands of the contractor as the specification described, and I cannot, in the circumstances, see any reason why they should suffer loss when the specification has been departed from. Respectfully yours,

ROBERT BRIGGS, C.E.

The Decimal System.—In "Money and Mechanism of Exchange," by Prof. W. Stanley Jevons, recently published in London, the decimal system is discussed at some length, with a conclusion that in the end it will predominate, but only from the hold which it has taken on the world; and accompanying the opinion that it is to be regretted, because "the duodecimal system is in various ways much more simple and convenient." This assumption of convenience as a fact and consequent reasoning that nothing but conformity is to be attained may be unanswerable in England, but it cannot be ever comprehended in America where the habit of using decimal money has incapacitated most people from the use or desire for any other.

Chemistry, Physics, Technology, etc.

THE EFFECT OF MAGNETIC AND GALVANIC FORCES UPON THE STRENGTH OF, AND DESTRUCTION OF IRON AND STEEL STRUCTURES.

By Charles M. Cresson, M.D.

(*Read before the American Philosophical Society, June* 18, 1875.)

Bars and Structures of Iron and Steel when allowed to remain at rest for a considerable time acquire measurable magnetic polarity.

Moderate percussion, alternations of heat and cold, exposure to the rays of the sun, especially with a long axis of figure parallel, or nearly coincident with a magnetic meridian of the earth have a tendency to develop and strengthen magnetic polarity.

Thus, Iron Bridges, Iron Vessels upon the stocks in progress of construction, and Iron Railway Tracks are particularly liable to acquire magnetic polarity.

It is asserted that the relative position of the long axis of Iron Ships with reference to the magnetic meridian materially affects their polarity and the facility of the correction of their compasses.

If the keels of such vessels be laid on a North and South line, they are supposed to acquire greater polarity, and to retain it more steadily than when laid East and West.

The evidence of an Iron Ship's polarity is exhibited to the greatest degree, by comparison of its effects upon its compasses when the vessel is sailing in an easterly or westerly direction.

A consideration of the following facts seems to favor the conclusion that magnetic bars of Iron should be better able to resist tensile strain than those which are not magnetic.

A thoroughly magnetic bar is one of which each end repels a pole of a magnetic needle. The centre of such a bar is neutral, that is attracts either end of a magnetic needle and repels neither.

If we break such a bar in half, we are possessed of two magnetic bars; that end of the original bar which attracted the south end of a magnetic needle continues to attract it, that which attracted the north end continues to do so, whilst the two new ends which had

formed the neutral centre of the original bar, each acquires a polarity opposite to the other, and also opposite to that possessed by its own opposite end. A continuance of this process, that is, the fracturing of each half until we have obtained such minute fragments of the bar as can be examined only under the microscope, still produces perfectly polarized bars, possessing all of the magnetic characteristics of the original bar, with varying, attracting, and repelling force according to some ratio of the relative length and thickness of the fragments.

Arguing upon this we are led to the conclusion that a continuance of this process must produce molecular magnets.

If we place magnetic bars in contact with each other, the north and south poles alternating and in contact with each other we obtain a metallic chain of considerable strength, although its component parts are not mechanically connected together. The closer the contact of the ends of the bars the stronger will be the chain.

If with isolated bars we can obtain a connecting force equal to many pounds by close contact, how much stronger must be the connecting force when exerted between molecule and molecule.

Such an argument undoubtedly leads to the conclusion that bars saturated with magnetic force should certainly be stronger than those that are not.

Faraday announced that "there existed lines of force within the magnet of the same *nature* as those without. What is more there are exactly equal in *amount* with those without. They have a relation in *direction* to those without; in fact are continuations of them, absolutely unchanged in their nature."

To determine the effect of magnetic force upon the tensile strength of Iron and Steel,* bars of each were selected and cut into suitable lengths for use in the breaking machine and numbered.

Nos. 1, 3, 5, etc., were broken in the usual manner.

Nos. 2, 4, 6, etc., whilst in the breaking machine were surrounded by a suitable coil of copper-wire, through which a current of galvanic electricity was passed during the operation of breaking.

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*The Steel employed in the experiment was "Jessop's Round Machinery," ½ inch rod—

and broke at { maximum, 127,934 lbs.
minimum, 125,694 lbs.
per square inch of section.

The Iron broke at { maximum, 59,948 lbs.
minimum, 56,887 lbs.
per square inch of section.

The results obtained from the magnetic Steel bars were about one per cent. less than those obtained from the non-magnetic, and from the magnetic soft Iron bars about three per cent. less than from the non-magnetic.

Both the Steel and Iron bars became heated whilst within the influence of the current of electricity, the soft Iron more so than the Steel.

It occurred to me that the depreciation of strength might have been caused by the rise of temperature† in the bars, and I accordingly prepared permanent magnets from alternate sections of a steel bar and repeated the experiments comparing the cold magnets with the unmagnetized sections of the same bar. The results showed no appreciable difference in strength between the magnetic and non-magnetic sections.

To test the matter still further, bars of Steel were so magnetized as to present a pole at one end, the other in the middle of the bar, with one end neutral, that is, one end of the bar attracted the North or South pole by a magnetic needle and repelled the South or North, and the other end of the bar attracted either pole of a magnetic needle.

Under these conditions if there was any effect to be had from the influence of the magnetic force, the bar should incline to break either at the central pole or at the neutral point between the poles.

The results of the experiments showed that there was no inclination to a choice of either location as the place of fracture.

The conclusion arrived at, is, that *the condition of magnetic polarity does not in any way influence the strength of steel bars.* With reference to the soft iron bars the comparison was not made, for the reason that they would not remain magnetic unless surrounded by the galvanic coil, in which case they became heated by the action of the current.

How far a change from fibrous to crystalline structure is affected by the influence of magnetism has not been ascertained, or whether there is any deterioration of the strength of iron or steel on such account.

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†For effects of temperature upon the tensile strength of Iron, see Report of the Committee of the Franklin Institute of Pennsylvania,—"upon the strength of materials employed in the construction of Steam Boilers." Experiments made at the request of the Treasury Department of the United States (Jan'y 4th 1831—Jan'y 5th 1837.)

Iron telegraph wires, in the course of time become brittle, and to such an extent that if the usual method of uniting them by winding each upon the other is attempted, they are frequently broken in the process.

From this it would appear that a passage of a strong galvanic current produces some molecular change effecting the strength of iron. Such conducting wires, however, are not necessarily or even usually magnetic. There can be no doubt, however, as to the deteriorating effect of *galvanic* force as an accelerator of oxidation or the solution of a metal.

Observations upon Iron Bridges and structures subjected to atmospheric influences and upon Boilers exposed to the action of heat and the chemical agents contained in ordinary waters lead to the conclusion that galvanic force is usually as great, and frequently a far greater cause of deterioration than mechanical wear. Indeed all of the operations of nature, organic and inorganic, both constructive and disjunctive, involve the production of more or less galvanic force or are the results of its action.

Motion, unaccompanied by any other apparent change than that of place, is a desturber of electric or galvanic equilibrium, and the converse is equally true. If it were possible to produce perfectly pure and homogeneous iron, then the generation of destructive galvanic currents by the contact of sheets or bars would not take place.

By exercising care in the selection of iron, especially that used for steam boilers, the deterioration from galvanic action can be reduced to a minimum.

Many steam boilers have come under my observation in which the corrosion was but slight, and affected all parts equally, others in which the metal of a single sheet only was attacked, the corrosion of which sheet protected the remainder of the boiler almost as efficiently as if the sheet had been replaced by one of the metal zinc.

The most striking instance of the effect of introducing a sheet of metal of greatly differing electro-condition, that occurs to me, is that of a boiler which had been in use for a considerable length of time without showing any unusual tendency to corrosion, when from some cause it became necessary to replace a sheet by a new one.

The result of the introduction of a new sheet was to set up at once a strong galvanic action by which every sheet in the boiler was corroded except the new one.

Samples of iron cut from the edges of the old and from the new sheets were placed in a bath to which a few drops of dilute acid were added and a connection made with a galvanometer, resulting in the production of a new current; the purer iron corroding, and protecting that which contained the greatest amount of carbon.

The inciting cause of the galvanic action was therefore judged to be the introduction of a sheet of iron electro-negative to those already in the boiler, its position in the electro-chemical scale depending upon the amount of carbon it contained.

The injurious effect consequent upon the junction of masses of wrought iron of varying electro-chemical properties, is, therefore, increased when *steel* is joined to wrought iron, as is frequently the case in locomotive boilers in the tubes and tube sheets.

Again by the junction of *cast iron* to steel or to wrought iron, the destructive effect is greatly intensified, and at times becomes quite as violent as when copper is made an element in the galvanic circuit in connection with wrought iron.

The necessity for the selection of iron with reference to its electric condition, applies equally to the material employed for Bridges or Vessels or Boilers or any structure which is to be built up from separate sheets and bars of iron.

It is or ought to be the habit of careful constructors to cut sample pieces from every sheet or bar of metal worked, and to make a trial of their quality by bending hot and cold, and to make frequent tests of tensile strength. Examinations as to electric-chemical condition can be made with equal facility. Determinations of the composition of the metal or of the percentage of carbon in it by chemical analysis are unnecessary; an ordinary workman furnished with a coarse galvanometer and a weak acid bath can ascertain the exact electro-condition of each sheet or bar more rapidly than he can examine the quality by the ordinary tests of bending on an anvil, hot and cold. With the metal of Bridges, Vessels, and especially Steam Boilers, the deterioration by corrosion is more to be feared than is mechanical wear.

Galvanic corrosion acts with greater vigor in locations that are usually inaccessible, such as the interior of joints or defective sheets or parts that are closely approximated, and the mischief is only suspected when it has progressed to such a degree as to become evidently

dangerous and the parts are in condition to require immediate attention and repair.

Attention to the precautions enumerated for securing mechanical and chemical fitness of the metal to be used for structures of iron, will undoubtedly promote economy and safety.

NOTE BY THE EDITOR OF THE JOURNAL.—It must be always remembered by the readers of the JOURNAL, that the Franklin Institute does not assume any responsibility for the statements or opinions advanced in papers which may appear in its pages, neither is the Institute in any way compromised by the views of the editor whenever he may express them.

The first portion of the foregoing paper carries with it, in negative results, an antidote to the evil of promulgating an occult reason for strength or weakness of iron. Some of its statements are a little questionable; for instance, it may be doubted if a bar or structure of *iron*, pure and simple, acquires magnetic polarity, or rather, retains it under any circumstances. It is generally known that all the iron of commerce, or in use for structural purposes, is *steely* to some degree, and the extent of the nature of steel in the material is in some ratio a limit to its capability to assume permanent magnetism.

The effect of the position of a vessel with regard to the points of the compass, when in construction, has been thoroughly investigated and determined; the value of that effect, however, is so influenced by the dissimilarity of the plates or bars in proportions of carbon, and by differences in the application of force upon them, by hammering, or in other ways, as to be very indefinite.

The reasoning that a magnetic bar should be stronger than one not magnetized, on a theory of internal subdivision, is somewhat wanting in logical force. It is difficult to comprehend how the attraction should multiply, except on the argument that two halves of a string are stronger than a whole one.

If the law were good, the subdivision need go no farther than Joule's celebrated magnets, where a fragment of iron of one-half grain weight supported by attraction a quarter of a pound (or 3500 times its own weight). This proportion would add nearly 56 lbs. for each sixteenth of an inch of length of bar of one square inch section—11,000 lbs. per foot of length.

It is very certain, that telegraph wires are *not* impaired in the least by the electric currents of service. Telegraph wire is hard drawn or rolled, and galvanized by a coating of zinc, and when laid at rest, without excessive tension, will last some unknown length of time. When strained from poles placed at great distances apart, contracted by the winter cold to the tension of a harp-string, when the gentle zephyrs from the northwest have played on them for many months, when occasional loads of ice of eight or ten times their own

weight have tested them—then the wire may be found to have become so brittle that it cannot be wound around its own diameter of 5-16 of an inch, with impunity.

But this part of the paper terminates very satisfactorily. Magnetism did not strengthen iron. It is the second portion not so conclusively disposed of, that leaves behind a possible assumption of dangerous character. It is a serious mistake to admit as a popular utterance, that we must look to "galvanic (voltaic?) force" as the *cause* of deterioration of boilers, or of iron structures of any kind. It is very certain, that an electric current produced by a voltaic battery will decompose a solution of a salt, and cause a crystal to be formed at one pole, and a gas to be eliminated at the other. It is also certain, that two dissimilar metals, in a bath of acid, which from chemical affinity will attack either, will act by the destruction of the one for which the acid has the greatest affinity, and a voltaic battery will be formed from which electrical currents can be taken. It may be admitted, that no deposition in crystalline form occurs without the agency or accompaniment of a current of electricity, and that no decomposition of metals by rusting is *unattended* by the development of a current. But the acid that destroys, and the salt that deposits, are precedent to, or coincident with the voltaic currents.

It is questionable, if at any temperature below the highest used in steam boilers, either iron or steel (iron with a small quantity of carbon in intimate but not chemical combination) will rust in pure water divested from oxygen. The acids requisite for the slow destruction of the boiler are supplied by the presence of oxygen. The presence of oxygen by absorption in all water, and its evolution by heating of the water, beside the vegetable acids generally to be found in small quantities, the decomposition of chloride of sodium, to some degree, when salt water is used; and the fat acids derived from tallow and oil, when condensed water from the exhaust of an engine is pumped back; all these supply acid requisite for the slow destruction of a boiler. The carbonate and sulphate of lime, which form the bases of incrustations are to be found in most waters, and in great abundance in some.

A perfectly homogeneous condition in the electro-chemical state of all the material of the boiler *might* be a protection from rusting of any part, and prevent the establishment of electric currents and preclude incrustation, but the equilibrium would be excessively unstable; the difference of temperature would obviously disturb it, and the supposition with our knowledge of the constituents of iron, either in the crude product or the finished material, is simply impossible. The effect of differences of heat on the electro-chemical condition of a piece of iron is quite equal to that proceeding from the presence or absence of small quantities of carbon. While the balance of

evidence is that without free (possibly ozonized) oxygen in water, iron of any grade (not spongy) will not decompose it at ordinary temperature; yet pure iron is acted upon with the greatest facility.

Pure iron, also, is nearly incapable of being worked in the furnace without burning up—as iron approaches purity it becomes workable without excessive waste only in Siemens' furnaces, where the gases of combustion are free from oxygen—and pure iron has very little comparative tenacity, and great ductility. Iron on the other hand, with an almost imperceptible proportion of carbon, (and possibly some other substances as substitutes), is tenacious, unyielding to near the point of rupture and suitable for boiler plates. With another small addition to the carbon, the iron becomes low steel, or so-called homogeneous iron, of yet greater strength and suitability. With other ratios of carbon there is found steel not suited for boiler work by hardness, although the strength may be further increased.

Imagine it to be feasible "for an ordinary workman with a coarse galvanometer and a weak acid bath," to select these qualities, the operation would be highly satisfactory if iron boiler plates were found in these four conditions solely. But there are other kinds of plates.

The exact place of the plates in their electro-chemical state does not detect the small increment of phosphorus or sulphur, and the iron may still be worthless. The remedy is simple: "Cut sample pieces from every sheet, 'bend them hot and cold,' and make 'frequent tests of the tensile strength.'" Following all these precautions and we shall have a great many professors and very few workmen, and our mechanics will go to less critical countries.

We shall, without doubt, have acquired a degree of excellence not yet attained, and until other precautions are suggested, such as the disuse of piled plates, because some have blisters, the use of drilled holes, because some punchings are imperfectly done and strain the sheet, etc., boiler making will have taken a step towards *perfection*.

In short, the improvement of boiler practice must move in the track already laid. Responsibility must urge upon the user of a boiler the necessity of excellence, and emulation must do the rest. The iron manufacturer will emulate to supply iron *better* suited, the workmen boilers better made, and the engineer boilers better planned. The scientific man can help them all, but he cannot make philosophers of them.

The question now really open to consideration is either how to obtain water free from injurious substances, or else to allow such substances to act upon some material, zinc for instance, for the protection of the iron. When this is settled, the destructive "galvanic (voltaic?) force" will be found to have disappeared.

FAYE—ON THE METEOROLOGICAL THEOREM OF ESPY.*

"A current of descending air can never be cold, for the current "warms itself by its own compression, at least in the normal state of "the atmosphere. There can then result neither rainfall nor the "condensation of the aqueous vapor in the strata traversed by it, but "rather something similar to that which one observes in the sand "storms of Africa and Asia."†

From this celebrated theorem, its author concluded some thirty-five years ago, and we still to-day conclude with him, that the movement of the air in our hurricanes, cyclones, water spouts, and tornadoes, can only be ascending: an idea so conformable to the old prejudice, according to which water spouts and tornadoes draw the water of the sea up to the clouds, that it was immediately adopted. This theorem as expressed by its author, and after him by nearly all meteorologists, is not to be accepted. It contains, however, something of that truth and usefulness which so forcibly impressed the Academy when Espy, in 1840, came to submit his labors to it. But so much of truth as I shall have occasion to deduce from this theorem, leads to some conclusions quite different from those which to-day are ordinarily connected with the preceding principle.

Let us enclose, high up in the atmosphere, by the aid of a cylinder and piston, impermeable to heat, some air taken at its natural pressure, p, and at its temperature, t; then let us force this apparatus to descend, traversing successive layers of atmosphere to the ground, where the final pressure is p'. What then will be the temperature, t', of the air thus compressed within the cylinder? This is a simple question of thermo-dynamics, the solution of which is given by the well known formula

$$T' = T\left(\frac{p'}{p}\right)1 - \frac{1}{r}$$

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* Translated by C. Abbe from *Comptes Rendus, Paris*, vol. 81, p. 109.

† Extract from the report of Messrs. Arago, Pouillet and Babinet, (*Comptes Rendus*, 1841, vol. 12, p. 454, etc.) Mons. Peslin presents very clearly the same theorem. (See *Comptes Rendus*, May 10, 1875): "I have demonstrated that if the movement be descending, as Mons. Faye would have it, then, first, there could not be any rain; second, the wind in a tempest would be very warm and very dry, and would present to an eminent degree, the characteristics of the wind called in Switzerland, Foehn. In a preceding article of the 12th of July, I have discussed the opinion of Meldrum, that has been by some opposed to my views."

γ being the ratio of the specific heats of the air at constant pressure and constant volume; T and T′, the absolute temperatures corresponding to the initial and to the final pressures p and p'. In Mr. Espy's time, thermo-dynamics did not exist, but we had an equation of La Place, as written thus by Poisson,

$$t' + \frac{1}{a} = \left(t + \frac{1}{a}\right)\left(\frac{p'}{p}\right)1 - \frac{1}{\gamma}$$

Where t and t' are the ordinary temperatures, and a the coefficient of dilatation of the air. At present, it is known that this latter equation is identical with the preceding; for $t + \frac{1}{a}$ is nothing but the temperature T, counted from the absolute zero. Mr. Espy has then, in 1840, correctly performed his calculations, and the Commission of the Academy, in 1841, has been able to assure itself as it has said, of their satisfactory exactness, without knowing a word of thermo-dynamics, without suspecting even, the meaning that this science to-day assigns to the reciprocal of a. Moreover, the numerical values of a and γ were known even then with a precision far greater than was necessary for these calculations.

Let us take for example, as has been done by Peslin, who has reproduced under a slightly different form some calculations of this kind, some air at 5000 meters altitude. In the normal state of equilibrium attributed to the atmosphere at this height, the temperature of this air should differ by 30° centigrade from the lowest stratum (a vertical decrease being supposed of one degree for 175 meters in altitude.) Making then for the lower strata $t' = 30$, and $p' = 0{\cdot}76^{m}$, and for the upper stratum, $t = 0$, we find, supposing the barometric formula of La Place applicable to this case, $p = 0{\cdot}42^{m}$. We have for the reciprocal of a, 273° (it was 266° in 1840) and as the normal air taken at an altitude of 5000 meters, and at 0° temperature contains very very little vapor, we should have to make $\gamma = 1{\cdot}41$, as for dry air. This air being by its compression forced further and further from its point of saturation, the above formula is applicable. It gives $T' = 324°$, whence $t' = 51°$. Thus the temperature of the air when it arrives at the bottom has been elevated to 51° by the compression that it undergoes, supposing as we have done, that there has not taken place any exchange of its heat with the surrounding air. Its excess of temperature with reference to the lower air will be $51° - 30° =$

21°. If it were saturated with moisture at an altitude of 5000 meters, it would be of extreme dryness on arriving at the ground.

But, in reality, the descending air traversing the atmospheric strata, will continuously give up its heat to these latter, according to an unknown law, and will receive aqueous vapor from them. This places us face to face with a new problem, where the cylinder referred to in enunciating Mr. Espy's theorem, can no longer be supposed impermeable to heat.*

In the second place, the supposition that we have made of an atmosphere in the normal state of equilibrium, excludes precisely the great perturbation that we are studying. The preceding theorem ought, then, strictly to be reduced to the following: The normal air of the upper regions being forced by descending to traverse successive strata also in their normal condition, tends at each instant to acquire a temperature superior to that of these strata. It will arrive at the ground with a temperature a little superior to that of the last or lowest stratum, and in a state of much greater dryness. The contrast between these will depend upon the velocity of the descent and upon the nature of the contact of this air with the strata traversed by it. And it is necessary to add that this proposition is inapplicable to all other cases, for if, beside the vapor of water this descending air should drag with it, or receive *en route* some water in a vesicular state like that found in the clouds, the preceding calculation would signify absolutely nothing. The air thus mixed with liquid particles would tend to maintain itself during its descent in a state of saturation, and the heat acquired by its increasing compression would be employed in vaporizing the aqueous vesicles at the rate of from 606 to 594 calories per kilogram of water, (between 0 and 20° temperature) under whatever form this liquid water presents itself. Let us suppose simply to fix our ideas that the air dragged into the descending current contains two per cent. of its weight of vesicular water, which is not even equal to the quantity of water contained in a state of invisible vapor in the lower stratum of air at the point of saturation. In order to vaporize this water, there will be necessary 12 calories for each kilogram of misty air, whilst the compression of the gaseous part as calculated above would itself produce only 12 calories. The phenomena as above described would, therefore, be reversed, the

* See Hirn's mechanical theory of heat, 3d edition, vol. 1, page 296.

upper air would traverse the successive strata, preserving a lower temperature, and would take heat from them in place of giving it to them; it would arrive at the ground colder than the lowest strata, and absolutely saturated, and even still preserving some vesicular water. These ideas are immediately applicable to water spouts. The cold air of the upper regions traverses the thick strata of clouds to whose increase it contributes, and draws with it into the lower transparent strata the material of these clouds which seems to form a vaporous prolongation of them downwards, under the ordinary conical form of a whirl; a quick gyration by accumulating the opaque and heavy particles at its circumference will produce around the descending column a nebulous sheath, more or less opaque,—at least, in so far as the heat and the dryness of each stratum thus traversed does not suffice to transform the whole into vapor, and then the water spout will become transparent in this portion. But ordinarily in full activity and in moist weather, it remains opaque down to the ground, or to the surface of the sea. This entire reversal of the effects predicted by Espy will be still more marked, if in the upper air there are found mixed with it the cirrus clouds which one sees constantly appearing in the upper currents as precursors of storms, and afterwards participating in the gyratory movement which produces them; for then it is no longer the atoms of water that need to be vaporized, but needles of ice whose temperatures are often far below that which we have adopted for a purely fictitious state of equilibrium.

This glacial air, charged with particles of frozen water, which descends by whirling over a vast circular space, traversing strata already saturated with moisture, gives rise, first, to an abundant precipitation of vapor; secondly, to rain, or even to the formation of hail, which so often accompany cyclones*. And if these various products, air, vapor, and drops of rain arrive at the soil with their temperatures differing but little from that of the last stratum, it is because they are rewarmed in traversing the intermediate layers. We see how far Espy was from applying his theorem to tempests, cyclones, hurricanes, etc. The only application that it is permitted to make of it, in my opinion,

* The constitution even of these hailstones is in accordance with this theory, and shows that the icicles of the very cold cirri agglomerating in the gyratory movement, which tends to accumulate them at its circumference, encounter alternately in their circular descent, layers of air simply saturated with vesicular water, which produces a transparent crust, and strata containing frozen particles, the re-union of which produces an envelope opaque like the nucleus.

is that which we have already indicated above. Let us take the first example, and consider our cylinder (always impermeable to heat, but supposed actually without gravity) at the moment when it is just above the ground. If the next instant we let it go, it will re-ascend in virtue of its surplus heat, like a hot air balloon, until it attains its primitive altitude, while its piston will rise little by little by the relaxation of the interior air. Now, a similar atmosphere, very nearly deprived of vesicular water, is encountered at every altitude above certain sandy regions, to which the great upper currents of the atmosphere arrive, only after having been deprived of their cirri and other clouds by the well-known action of high plateaus or chains of mountains placed in their way. If the gyratory movements which are formed in the ærial currents happen to pass above such deserts, they bring down only more of the super-heated air of an extreme dryness. This air, lighter than the surrounding air, will tend then, when once it is disengaged from the gyratory motion by the resistance of the soil, to re-ascend tumultuously all around the whirlwind, and, moreover, it will ascend the higher, in proportion as in descending more rapidly, it may have given out less heat to the strata traversed by it. Then the torrents of sand swept up from the soil and projected afar by the geometrically circular work of the cyclone will be carried tumultuously upwards, all about the latter by the air which has just escaped from it, when seized by the prevailing winds, they will be transported to great distances. But it is not the whirlwind itself which will have elevated this torrent of dust into those upper regions, as it is generally thought; but it is, on the contrary, the ascending counterpart of the phenomena which produces this effect, and consequently those distant transports of clouds of dust so well studied by Tarry.

This same theorem of Espy, when restricted to its true field, reduces to nothing the hypothesis of descending cyclones, of beautiful weather, with decreasing temperatures, that Hildebrandsson recently explained in a memoir otherwise very interesting, where, after having repudiated my ideas, he substantially restricts the movements of the atmosphere to two kinds of winds: the ascending winds of bad weather, and descending winds of beautiful, and often cold weather. Thus we see that the truth as contained in the theorem of Espy is reduced to a very small item, and this part is completely in accordance with the idea I have entertained. This history is instructive. It shows

how much our mind is inclined, even in a very simple mathematical study of natural phenomena, to lose sight of the conditions or the suppositions which alone have prompted the employment of this powerful instrument and to formulate general conclusions which we imagine to have been demonstrated with the rigor of the formula and figures. I have still some remarks upon another subject before closing. I have shown that the pretended storms of aspiration should be incapable of changing their place, and consequently of presenting the grand phenomena of movement of translation which brings into our climate the cyclones primitively formed in the torrid zone. Mohn has set forth, in his beautiful study of the storms of Europe, the fact already recognized in other regions near the equator, that it ordinarily rains more in advance of the cyclone than in the rear; and he has concluded thence that a rarefication is produced in advance. This latter should determine the entire cyclone to advance as a whole in the direction where the atmosphere presents the greatest humidity. My reply is: first, the cause assigned should tend to indefinitely elongate the cyclone towards the front, and not to make it march along as a solid body; second, there should be in its advance a vast barometrical depression, such as in fact exists only at the interior, and whose maximum is found at the centre; third, the cyclones moving constantly from the equator, march toward the higher latitudes, whilst the humidity, on the contrary, increases from the higher latitudes towards the equator; fourth, in the hypothesis of storms of aspiration, however slightly gyratory, like those of Mohn, there would not be any constant ratio between the direction of a stream of air moving inwards below, and that of the same air after it takes a centrifugal movement outward, above; fifth, in fact, the water-spouts, which are also cyclones, advance very easily, without there falling a drop of rain.

As to the general movement of the lower atmosphere invoked by Messrs. Espy and Peslin, it affects almost always a direction entirely independent of that of cyclones, great or small, or rather it is zero. The truth is far more simple. The cyclones follow the advance of the upper currents, where they have their birth, and these currents have not any direct relation to the actual state of the lower atmosphere.

There remains a calculation wherein Peslin undertakes to show that the gyrations of cyclones ought to result from the rotation of the earth. I will request my friend to extend a little farther, to the fifth degree of latitude, for example, the calculation that he has made for the forty-fifth degree. Some of the water-spouts and tornados have a violent gyration; and for some cyclones themselves, it is very clear that the cause indicated does not exist. Mr. Peslin has even pretended that some of these phenomena, so eminently gyratory, ought to be banished from the category of cyclones. Ought I to speak of the barometric depression which we have cited so often as a palpable proof of the power of aspiration? Undoubtedly the level of the sea tends to elevate itself under any cyclone, by virtue of this barometric depression, the latter being from one to five centimeters of mercury; and the change in the level of the ocean corresponding thereto tends to elevate it from one to six decimeters.

I believe I am able here to close this long discussion, where I have occupied myself, exclusively with facts. My researches upon the mechanical constitution of the sun, have led me at first to questions new to me. Perhaps I have thus contributed to dissipate the prejudices that have weighed heavily upon one of the most interesting of our sciences, by putting in full view, and explaining the beautiful laws of tempests, so necessary to our mariners, and so strangely misconceived to-day; to prepare finally the experimental base in which the mechanics of the gyratory movements in fluids have, until now, been deficient. If it is so, it will be correct to say that studies purely solar, have thrown some light upon terrestrial phenomena.—*Paris Comptes Rendus*, vol. 81, pp. 109 to 115.

The Wonders of the Microscope.—The last number of the *Microscopical Journal*, (Sept. 1), describes the existence of Flagella (tails or probosces) in Bacterium termo. The body of this object is warp-shaped and measures, each part, about 1-14,000 an inch in length, and 1-45,000 an inch in breadth, and has been before observed. It is now seen to have a "flagella" at each end about as long as the two parts of the body, or 1-7000 part of an inch, and not to exceed 1-1,000,000 an inch in width, and so *thin* as to be undiscernable on the side view. This "flagella" has muscular power and coils and lashes rapidly.

The limit of microscopic observation is not yet reached, and each new attainment has merely been made to be surpassed.

PHYSICAL PROPERTIES OF CARBONIC ACID.

By JOHN W. NYSTROM, C.E.

The strange action of carbonic acid has at all times occupied the attention of operative minds speculating to use the same for motive power, but we have heretofore not had sufficient experimental data to define its law of action. The late experiments on carbonic acid, made by Dr. Andrews, published in the September number of this JOURNAL, are therefore welcome to those who labor on that subject.

The object of this article is to treat Dr. Andrews' experiments with sufficient mathematics to render them more available in practice.

V = volume of carbonic acid gas of temperature T, centigrade, and of pressure P in atmospheres, compared with the volume at zero centigrade, and under atmospheric pressure.

(1) $$\text{Volume } V = \frac{1}{P} + \frac{T - 1{\cdot}4P}{200P}$$

(2) $$\text{Temperature } T = P(200V - 1{\cdot}4) - 200.$$

(3) $$\text{Pressure } P = \frac{T + 200}{200V - 1{\cdot}4}$$

The pressure varies, inversely as the volume, when $T = 1{\cdot}4P$.

The following table I is calculated from these formulæ.

TABLE I.—Volume of Carbonic Acid Gas of different Temperatures and Pressures.

Centigr'de Temp. T.	PRESSURE, P, IN ATMOSPHERES.					
	1	10	20	30	40	50
0	0·993	0·093	0·0430	0·02633	0·01800	0·013
10	1·044	0·098	0·0455	0·02800	0·01925	0·014
20	1·098	0·103	0·0480	0·02966	0 02050	0·015
30	1·148	0·108	0·0505	0·03133	0·02175	0·016
40	1·198	0·113	0·0530	0·03300	0·02300	0·017
50	1·248	0·118	0·0555	0·03466	0·02425	0·018
60	1·298	0·123	0·0580	0·03633	0·02550	0·019
70	1·348	0·128	0·0605	0·03800	0·02675	0·020
80	1·398	0·133	0·0630	0·03966	0·02800	0·021
90	1·448	0·138	0·0655	0·04133	0·02925	0·022
100	1·498	0·143	0·0680	0·04300	0·03050	0·023
110	1·548	0·148	0·0705	0·04466	0 03175	0·024
120	1·598	0·153	0·0730	0·04633	0·03300	0·025
130	1·648	0·158	0·0755	0·04800	0·03425	0·026
140	1·698	0·163	0·0780	0·04966	0·03550	0·027
150	1·748	0·168	0·0805	0·08050	0·03675	0·028

The volume corresponding to $T = 0$ and $P = 1$, should be the unit 1, instead of 0·993 in the table, but the course of Dr. Andrews' experiments indicate that the primitive volume had been 0·993.

When the temperature is expressed by Fahr. scale, the formula for volume will be

$$(4) \qquad V = \frac{1}{P} + \frac{(T - 32) - 2{\cdot}52P}{360P}$$

When the pressure is expressed in pounds per square inch $= p$, and the temperature by Fahr. scale, the formula for volume will be

$$(5) \qquad V = \frac{14{\cdot}7}{p} + \frac{(T - 32) - 0{\cdot}1743p}{24{\cdot}49p}$$

Dr. Andrews' experiments extend only to three temperatures and three pressures, which is not sufficient for determining the law of volume which requires at least five points of temperatures and pressures. Any kind of curve can be drawn through three points.

The data given by Dr. Andrews indicate that his experiments have been made with great care and precision, and I hope he will complete the experiment to the requisite five points of temperatures and pressures.

The following table is respectfully submitted to Dr. Andrews to fill up, in order to establish the law:

Centigrade Temp. T.	Pressure in Atmospheres.				
	1	10	22·26	31·06	40·06
0·	.....	.....	.....	.....	.....
6·05	.....	.....	0·03934	0·02589	0·01744
20·	.....	.....	.....	.....	.....
63·7	.....	.....	0·05183	0·03600	0.02697
100·5	.....	.....	0·05909	0·04160	0·03161

In all kinds of experiments where a quantity depends upon two independent variables whose laws of variation are unknown, a table of this kind should be completed in order to establish the sought law. When carbonic acid evaporates from liquid to gas, or condenses from gas to liquid, the relation between the temperature and pressure is as follows:

T = temperature Fahr. of the liquid and gas.

P = pressure in atmospheres.

$$(6) \qquad P = \frac{(T + 260)^4}{208513600}$$

log 8·3191344.

$$(7) \qquad T = 120{\cdot}17\sqrt[4]{P} - 260.$$

log 2·0797838.

p = pressure in pounds per square of carbonic acid vapor.

$$(8) \qquad p = \frac{(T + 260)^4}{1421700}$$

log 7·1527888.

The above formulæ are deduced from the experiments of Pelouse and Faraday. It appears from those experiments that carbonic acid freezes to solid at the temperature 260° Fahr. The freezing point of liquid carbonic acid is variously given by different authors. Olmstead says —85°, but Faraday experimented with liquid carbonic acid at —148° without it freezing.

TABLE II.—Properties of Carbonic Acid Evaporating from its Liquid, or Condensing from Gas.

Pressure.		Fahr.	Pressure.		Fahr.
Atmos., P.	Pounds, *p.*	Temp., T.	Atmos., P.	Pounds, *p.*	Temp., P.
0·0	0·0	— 260	15	220·5	— 24
0·1	1·47	— 192	20	294	— 6
0·2	2·94	— 180	25	367·5	+ 9
0·3	4·41	— 171	30	441	21
0·4	5·88	— 164	35	514·5	32
0·5	7·35	— 159	40	588	42
0·6	8·82	— 154	45	661·5	51
0·7	10·29	— 150	50	735	59
0·8	11·76	— 146	60	882	74
0·9	13·23	— 143	70	1029	88
1	14·7	— 140	80	1176	99
1·5	22·05	— 127	90	1323	110
2	29·4	— 117	100	1470	120
2·5	36·75	— 109	110	1617	129
3	44·1	— 102	120	1764	138
3·5	51·45	— 96	130	1911	146
4	58·8	— 90	140	2058	153
4·5	66·15	— 85	150	2205	160
5	73·5	— 81	160	2352	167
6	88·2	— 72	170	2499	174
7	102·9	— 65	180	2646	180
8	117·6	— 58	190	2793	186
9	132·3	— 52	200	2950	192
10	147	— 47	220	3234	207
12	176·4	— 36	238	3500	212

The preceding table, II, is calculated from the formulæ, and agrees with the experiments of Dr. Andrews, as follows:

Temperatures.	Pressures.	Atmospheres.
Fahr.	Andrews.	Nystrom.
32	35·04	35.
72	61·13	59.
83	70·3	67.

Dr. Andrews' experiments give higher pressures at high temperatures than my formulæ, which correspond with the experiments of Pelouse and Faraday.

THE QUANTITIES OF AIR, CARBONIC ACID GAS, MOISTURE AND HEAT ACCOMPANYING RESPIRATION.

The following is a note of interest as relating to important questions in ventilation. The inquiry of Dr. Smith is the most complete one made to this day, and a summary of its results accompanied with an estimation of corresponding heat and moisture will prove advantageous in some cases.

NOTE UPON DR. EDWARD SMITH'S inquiries into the phenomena of respiration. Proc. Roy. Soc., 1859, vol. ix, page 611, et seq.

Four persons were experimented upon, viz.: Prof. Frankland, Dr. Murie, Dr. Moul, and Dr. Smith (the writer.)

The result of experiments showed 18 to 20 respirations per minute of 39·5 to 30 cubic inches of air for each respiration. There were 4·63 to 5·72 pulsations to a respiration, the younger person of the four having the least number.

The quantity of air equals 583 to 365 cubic inches per minute. [If it is assumed that the air was at 62° and had 65 per cent. of humidity = (54½° dew point) = 527·4 grains of air per cubic foot, or 0·305 grains per cubic inch.]* The quantity then equals 178 to 111 grains of air per minute. The carbonic acid gas emitted varied from 10·43 grains to 6·74 grains per minute—equals 1 grain to 54·7 cubic inches to 1 grain to 58 cubic inches of air—or about 6 per cent. of the air exhaled was carbonic acid gas. Taking the fresh air of inhalation to have been 77 per cent. A + 23 per cent. O ∴ that exhaled becomes $77A + \frac{408}{22}O + [C\frac{36}{22} + O\frac{96}{22}] = 77A + 18{\cdot}55O + 6\overline{CO}_2 = 101{\cdot}64$ ∴ a gain of weight for constant volume at 62° of $1\frac{3}{5}$ per cent. The volume being unaffected by the chemical union of a part of the oxygen with carbon from the blood. Supposing the air to have been inhaled at 62°, and supposing also that the breath was exhaled from the nostrils or mouth at 90° without change of dew point, the volume would have become, if air only, $\frac{527}{509}$, but if loaded with moisture, $\frac{527}{494}$. The effect of heat upon density of carbonic acid gas may be taken as the same as upon air. Whence the density of the expired breath at 90° compared with that of fresh air at 62° = $\frac{494}{527} \times 1{\cdot}0164 = 0{\cdot}9532$. The emitted breath being nearly 5 per cent. less weight than the fresh air.

The quantity of moisture in air of 62°, and 54½° dew point (= 65

*Glaisher's table, barometer at 30″, Guyot, have been used for the figures given as sufficiently accurate for the estimate results.

per cent. humidity) is 4 grains per cubic foot, that in air of 90°* saturated is 14·5 grains, and for 1·05 cubic feet of air equals 15·2 grains—addition of moisture (extracted from the lungs, etc.) = 11·2 grains per cubic foot.

This quantity of moisture per cubic foot of air inhaled gives to 178 or 111 grains of air per minute = 3·7 grains to 2·3 grains of moisture per minute.

The removal of oxygen from the air equaled $\frac{4\cdot45}{23\cdot00}$ or 18·5 per cent. of the entire quantity of oxygen present.

RESUMÉ OF RESPIRATION EACH MINUTE.

0·338 to 0·211	cubic feet	of fresh air	at 62°	inhaled.
178 to 111	grains	"	"	"
10·4 " 6·7	"	" carbonic acid	at 90°	exhaled.
3·7 " 2·3	"	" vapor	"	"
171·2 " 106·2	"	" impure air	"	"
185·3 to 115·2	"	" total exhalation	at 90°.	

The quantity of carbon taken up = $\frac{6}{22}$ of the carbonic acid gas
=2·85 to 1·82 grains of carbon consumed in the lungs.

An examination as to the quantity of heat developed by the combustion and absorbed by evaporation is as follows:

The total heat of carbon burnt to carbonic acid gas = 14·500 units = 2·07 units per grain. (In this case the total heat is given out, as but 28° of elevation of temperature of escaping gases is allowed.) Whence, there are given out each minute,

5·75 to 3·73 units of heat.

The heat abstracted for vaporization = 1062 units per pound of water 98° to 90° (the temperature of the lungs being assumed at 98°) = 0·152 units per grain of same temperature. Whence, there are expended in formation of vapor in the lungs per minute,

0·56 to 0·35 units of heat.

Demanding about one-tenth the heat produced by combustion of carbon. The quantity of heat expended on heating the air of respiration ∴ 178 to 111 grains per minute × 0·238 (specific heat of air)

* It is not proper to assume this moisture to exceed the saturation of air at 90°. It is certain that the nostrils or mouth do not exceed this temperature, or certainly 92°, and that if more moisture than saturation were exhaled, it must condense in them to the final elevation of temperature of these parts. The breath does not show any indication of excess of vapor, except when expelled into colder, nearly saturated air.

= 42 to 26 × 28° (elevation of temperature 62° to 90°) = 1176 to 728 ÷ 7000 (grains per lb.)

= 0·17 to 0·10 units of heat,

or about two-sevenths the quantity expended in formation of vapor.* These figures leave nine-tenths of the heat evolved to be expended in radiation, convection, and evaporation from the surface of the body and in work. The foregoing figures are maximum and minimum for the *working* day.

The author gives for a day's combustion of carbon,

0·414 lb. to 0·280 lb.

Dr. Smith and Prof. Frankland being the exemplars—equivalent to the general average of carbonic acid gas per minute,

7·305 grains to 4·98 grains.

The quantity of carbonic acid gas increased after each meal and declined from the largest quantity with some uniformity of rate. It also increased with exercise and fell off at rest—in profound sleep to 4·5 grains per minute, and to 6·1 grains at other moments in the night, and decreased as the temperature rose.

The effect of increase of temperature (neither heat or dew point stated) was that the quantity of air was decreased 30 per cent., the rate of respiration 32 per cent. and the carbonic acid 17 per cent. [From this it would appear that combustion was more complete with warm air, and that over 20 per cent. more of the oxygen of the air is abstracted in warm weather, (temperature not given)]. It was shown that "while sudden changes of temperature cause immediate variation in quantity of carbonic acid, a medium degree, as of 60°, is accompanied by all the variations in the quantity of carbonic acid, and that there was no relation between any given temperature and quantity of carbonic acid at different seasons. Whatever was the degree of temperature, the quantity of carbonic acid, and all other phenomena of respiration, fell from the beginning of June to the beginning of September. Atmospheric pressure had no influence on seasonal or other changes. The exertion of walking two miles per hour induced an exhalation of 18·1 grains of carbonic acid per minute, and at three miles per hour of 25·83 grains. The effect of the tread-wheel at Coldbath Fields Prison was to increase the quantity to 48 grains per minute. B.

* There are some discrepancies in the above which have come from Dr. Smith's own figures, 178 : 111, is not the same ratio as 10·4 : 6·7.

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EDITORIAL.

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